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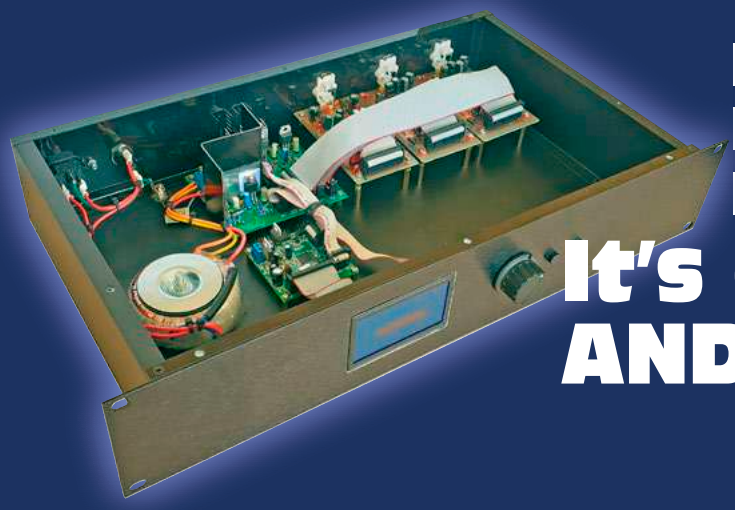

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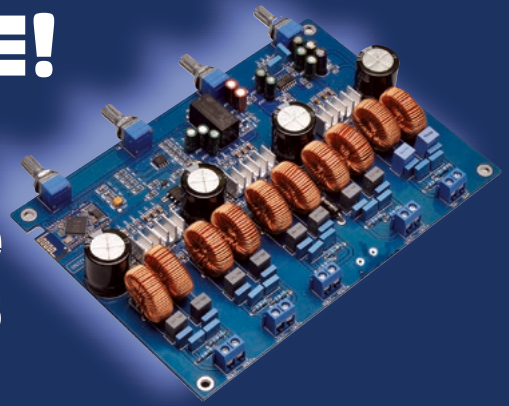

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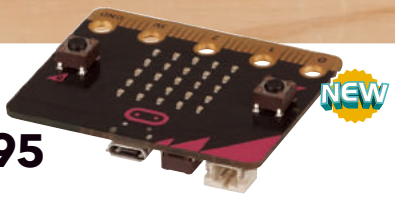

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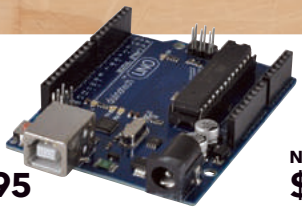

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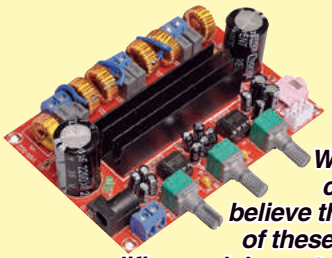

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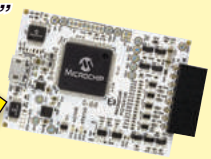

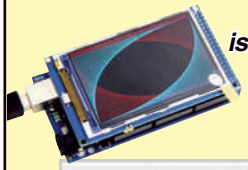

When a 2.4" or 2.8" display just isn't good enough . . . use a 3.5" instead – Page 86

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Editorial Viewpoint

"Crippleware" possibly to blame for two airliner crashes

No doubt you have heard about the two Boeing 737 Max 8 airliners which crashed in the last six months: Lion Air flight JT610, which crashed on 29 October 2018, killing 189; and Ethiopian Airlines flight 302, which crashed on March 10, killing 157.

You may have also heard that there is a suspicion that a fault in the angle-of-attack (AOA) sensor, which controls the MCAS anti-stall system, led to both crashes. This system can move the nose of the aircraft up or down if it thinks the aircraft is in danger of stalling. But faulty sensor data could lead it to 'fight' the pilots during normal flight.

(A report on the flight 302 crash, unofficially released as I am writing this, claims that there was no indication of damage to the AOA sensor. But it still seems that MCAS was a factor in both crashes.)

In a truly bizarre engineering decision, although these aircraft have two AOA sensors, only one was used as an input to the MCAS system. I can't understand that; if you have redundant sensors, why not use them? And how could they have thought that MCAS did not need redundancy, when it affects how the plane flies?

At the very least, if the two sensors were giving different data, MCAS could be disabled on the basis that it's better to do nothing than act on suspect data.

But even more damning to me is the fact that the aircraft were fitted with a warning system which tells pilots when the two sensors are giving conflicting data (which would be required even if MCAS paid attention to both sensors). But on both doomed aircraft, it had not been enabled because that feature cost extra!

I'm sorry, but these sensors were inputs into a system which affects how the aircraft flies. Charging extra for a safety system which is just activating a pre-existing warning light is wrong on so many levels. I understand that this system will now be enabled on all 737 Max 8 aircraft via a software update.

I think that's called closing the stable door after the horse has bolted.

I'm not the kind of person to get worked up about little things, but it annoys me when manufacturers sell me an expensive product which has extra hardware features, but they won't enable them unless I pay more.

This practice is known as "crippleware", which is when "vital features [of software or hardware] ... are disabled until the user purchases a registration key".

While I don't necessarily mind paying a little bit extra to enable more features, it isn't unheard of for the cost of these extra features to add up to way more than what you pay for the item in the first place! That makes me very annoyed.

And it isn't just aircraft where safety features have become crippleware. Every night I see people driving around without their headlights on. That's dangerous. There have been times where I have come close to having a collision with such a vehicle, as I could not see it until the last second.

In modern vehicles, this can be easily solved by the addition of a ten cent LDR to detect the ambient light level, a few lines of code to switch on the headlights when it's dark and maybe an extra transistor or relay to do the switching.

We're hardly talking sheep stations to implement this basic safety feature.

In some cases, automatic headlights can be enabled by plugging a laptop into the car and twiddling a bit in the ECU. And yet, many manufacturers charge several thousand dollars for the "options" package which includes this feature.

I think this should be made mandatory on all new vehicles. It's a fundamental safety feature which costs almost nothing to implement.

And I'd hate to have been involved in designing the 737 Max 8, especially the MCAS or related systems. They're going to have some very awkward questions to answer.

Nicholas Vinen

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Amateur radio could be useful in emergencies

David Williams (SILICON CHIP, March 2019) is spot on when he observes that we have all been put in a very vulnerable position since the NBN was introduced.

As well as questioning how long all the battery backups will last to keep all this internet-based infrastructure going in a disaster, he asks how long the phone towers will continue to operate.

But there is another problem with relying on the mobile phone network in a disaster scenario, and it's that the towers can be overwhelmed with calls in these situations, making the network virtually unusable. This leaves absolutely no communication left for victims to call for help.

Communications between emergency services and dispatchers has improved considerably from the disastrous days of the Ash Wednesday fires, when my amateur radio colleagues had to liaise between emergency vehicles with incompatible frequencies.

Since then, I have seen a general loss of interest in radio transmission as even some of my colleagues have moved their communications to chat rooms on the internet.

Here in central Victoria, members of the Bendigo Amateur Radio and Electronic Club (BAREC) have realised there is one thing that will always work when everything else has failed, and that is radio transmissions powered by batteries.

To this end, we are now training members of the public, who live in remote areas, to pass the basic Foundation Amateur Radio Licence which allows them to communicate with repeaters and monitoring stations outside the danger area. We're told that they now feel a greater sense of security and connectedness.

And of course, they can then use their new found skills to explore the hobby further. SILICON CHIP has covered radio and antenna projects before and it would be fantastic to see more of that in future.

Tony Falla, VK3KKP/G8HIM, Castlemaine, Vic.

Design flaw in Adjustable Active Crossover PCB

I have found a problem with the latest RevD version of the PCB for the Adjustable Active Crossover (September-October 2017; **siliconchip.com.au/Series/318**). If you power it from a centre-tapped mains transformer, when you switch the power switch S1 off, the two transformer windings are shorted out.

I was initially puzzled because the unit seemed to work perfectly, but always had a blown fuse when I next went to use it.

The short circuit designed into the board took me some time to find! It's because the front two pins of switch S1 are connected to a large section of copper on the board. This is clear in the image of the PCB pattern on pages 70 & 71 of the October 2017 issue.

With a bit of difficulty, I desoldered my switch and cut the front two pins off it. This turns the switch into a DPST version, and prevents the normally closed pins from being shorted to the centre pins when the switch is in the off position. The two plastic struts align the switch anyway and keep it in position.

Other than that, this was a great project to build and allows some interesting experimentation with speaker designs and audio electronics. I recently acquired a new Keysight EDUX1002G DSO, and its frequency response analysis function showed that the markings for the cross over adjustments are pretty accurate.

Stephen Hockey, Rosanna, Vic.

Response: sorry about this oversight. That large area of copper was provided to help anchor the switch firmly to the board when soldered. It should have been separated down the middle, to prevent the switch from shorting out the transformer when off. This has been fixed in RevE, and we will have RevE boards available for sale soon.

More preamplifier inputs wanted

Your magazine always provides articles and projects of interest. For some time I have needed a multi-input preamplifier; however, your 2007 and 2011 designs only cater for three inputs. Fortunately, I stumbled on the October 2005 Studio Series stereo preamplifier article (**siliconchip.com.au/Series/320**), which provides for five inputs.

Discovering that PCBs were still available for that preamp meant that it was all systems go! I have two different applications for the preamp, so I have ordered two PCBs.

As the 2005 design specified OPA2134 op amps, which are difficult to find and also are quite expensive, I decided in place of them to use NE5532s. The November 2011 article is very interesting in the way it describes the performance differences affected by different capacitor types and values and methods for keeping impedances low for good noise and distortion performance.

I suppose the modern audio analysis instruments that you have enable performance improvements to be analysed to a much greater level of detail than was the case in earlier years.

On the subject, your Universal Regulator Mk2 design (May 2015; **siliconchip.com.au/Article/8562**), while offering a lot of flexibility, does so at the cost of forcing the builder to restrict capacitor choice to 85°C types, due to their smaller diameter. I much prefer to use 105°C types for better long term reliability, especially in our

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environment where not all equipment will be used in air-conditioned areas.

However, to use the higher rated capacitors would have called for a larger PCB, which would not have suited the project's aim. Nevertheless, I consider this to be a major flaw in the design.

Richard Kerr
Cessnock, NSW.

Nicholas responds: we are planning to offer an upgrade to our most recent preamplifier design (March-April 2019; siliconchip.com.au/Series/333) to provide six stereo inputs with remote control and pushbutton switching. We are hoping that this will also be able to be built as a standalone audio input switcher.

The main reason for using an OPA2134 over the NE5532 would be its higher input impedance as it has JFET input transistors. If that isn't required, NE5532 or LM833 would be my choice. They are both cheap and excellent performers for audio (low/noise distortion).

I also much prefer using 105°C capacitors as they have a much longer life even at lower operating temperatures. It is true that they are generally larger than their 85°C rated equivalents; however, you can purchase relatively small 105°C-rated capacitors with good MTBF figures.

You can see in the Universal Regulator article (May 2015) that the capacitors used have considerable room around them. For the 2200µF 25V capacitors, you can use diameters up to 16mm (18mm if you're pushing it) which gives you hundreds of options for using 105°C rated capacitos.

For example, you could use Nichicon UBT1E222MHD which is 16mm in diameter and rated for 10,000 hours at 125°C. And the 100µF 25V capacitors can be up to 10mm in diameter which gives you plenty of high-reliability, long-life options.

By the way, electrolytic capacitors are now available which can handle operating temperatures up to 150°C!

Much better to repair than replace expensive consumer goods

I read Nicholas' comments in the March issue, on the current state of affairs regarding repairable consumer goods, with a smile on my face.

I spend a fair amount of time doing just that for friends, neighbours, friends of friends etc. Many people are reluctant to repair equipment because manufacturers can charge more for parts and repairs than the original item cost when purchased new. However, this becomes a major problem when parts are no longer available...

For example, I was trying to repair a wide-screen TV where the main CPU was history (along with the EEPROM). Although I could purchase and fit a new CPU and EEPROM, the firmware wasn't available, and neither were the startup operating parameters stored in the EEPROM. So I couldn't fix it.

I have another relevant anecdote about my Holden Vectra; a very nice car that was a joy to drive, powerful yet economical. One day I was driving home from Brisbane and it stopped. To cut a long story short, it needed a part which was no longer available. The number cast into the part by Holden didn't appear in any manual, and the Holden parts computer system didn't recognise it.

After waiting over a week for Holden to locate this part, I eventually found one in the UK. I bought two in case it failed again!

How long will it be before we have to throw away larger and theoretically 'durable' items due to the high repair costs and higher parts cost? How long before manufacturers decide to pull all support for given a product shortly after it goes on sale? When spare parts or firmware are no longer available, what happens then?

Then we find components with no identifying marks, MPUs that destroy themselves if anyone tries to download the code they run on and PCBs fully encased in resin preventing access to the boards and components on them.

I understand intellectual 'property rights' and copyrights, and they do have their place, but what about consumers rights? What does the consumer do if parts are no longer available and the new software or firmware will not run on the equipment they want repaired?

Technology is amazing and has been integrated into our everyday lives, but let's not allow the manufacturers of said equipment to control our finances or the global economic markets. We bought it, we own it and we use it, why are we being denied the right to have it repaired?

My PC keeps updating itself even though updates are turned off and one such update (for Windows 10) caused me to lose the use of my USB ports!

As my keyboard and mouse are both USB models, It was a struggle to remove that update and fix the mess it left behind.

Fixing broken products makes more sense. Products with a decent working lifetime make sense. And yet consumers have fallen right into the "just buy a new one" trap!

Comments: under existing Consumer Law, manufacturers cannot withdraw support for a new product – it must be supported for a "reasonable" time. Although, what that means exactly is anyone's guess.

Dave Sargent,
Maryborough, Qld.

Extension leads for bench supplies

Sometimes I need to have power some distance from my lab power supply. My solution to this problem was to make some extension leads up.

One end of the twin-core cable has piggyback banana plugs (so I can double-check the meter output or run a second cable) that plugs into the existing sockets. The other end has one of those screw terminal joiner blocks so I can connect any wires in.

This means that I can power up a prototype in the middle of the room, without worrying about using battery modules. I might need a longer one for greater freedom of movement. This would have the benefit of saving on batteries during development.

Darcy Waters,
Wellington, New Zealand.

Comment: keep in mind that depending on the current draw, you could have a significant voltage drop across such a cable. One of our bench supplies has separate sensing terminals so it would be possible to create kelvin probe style wires to suit it (they would need four cores although the two sensing wires could be thin).

Although it's awkward, we generally prefer to run a mains extension lead to the bench supply and put it on a wheeled trolley to get it close to the load, both for the convenience of front panel access and to get decent voltage regulation.

Electrical safety standards not being properly enforced

Your editorial in the April issue made me pretty angry. I started out in electronics pulling apart mains-powered equipment that had failed due to bad design or poor quality components.

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In my case, I was messing about with old black & white TVs, playing with the HT and zapping my brother or the plants in the garden, much to my parents' dismay.

I have been involved in electronics for over 40 years now and have seen the changes in the standards to which goods are manufactured. Some poorly made and, in my opinion, dangerous equipment has come in from overseas.

This equipment somehow makes its way onto our shores and ends up installed into peoples' homes, just waiting for some unsuspecting person to be killed due to the relevant government body not doing its job and halting the import of this junk.

The articles and projects published in Silicon Chip and its predecessors (*EA*, *ETI*, *AEM* etc) have always been well thought-out with regards to electrical safety.

What is of even more concern is the lack of backup for 000 emergency calls with the NBN roll-out. It's typical government stupidity; I am sure there will be many more deaths from people not being able to call the fire brigade, police or ambulances in emergencies.

Anon.

Some sellers on AliExpress are unscrupulous

There is no magazine in the world like Silicon Chip. Keep up your great work. I notice that you occasionally refer readers to products sold via AliExpress. I have been buying bits and pieces from AliExpress for about 12 months with no problems. But in January I was sent goods not as I requested. On checking my credit card statement after they arrived, I found a second charge of a similar amount taken by them on the same day but with no reference.

It is a total nightmare trying to get anything out of these people. You can only chat with them online via their website, but I find the interface very awkward to use. I have spent some three hours over a month and have gotten nowhere with them. I requested they email me so we could communicate properly, but they refused.

I've had occasional problems with Amazon and PayPal before, but I was always able to pick up the phone and talk to someone for a satisfactory resolution. So, I won't be buying on AliExpress in future.

Ron Cooper,
Collaroy, NSW.

Response: we have had mostly good luck with AliExpress, but as you say, when things do go wrong, it can be a real nightmare. There have been a few times that we have received counterfeit, defective or incorrect goods and have been unable to get a refund. In some cases, we have gotten a partial refund, but that hardly seems fair when we did not receive the items that we ordered.

But it's a bit difficult to recommend that readers avoid the site for these reasons because they have a great range of products at very low prices and even if you allow for say 5% of your purchases to 'go wrong', you're still getting a pretty good deal overall.

Having said that, it's still very frustrating when their dispute resolution process finds in favour of shonky sellers. You need to keep in mind the usual slogan when it comes to purchasing goods: "caveat emptor" – buyer beware!

Solar bilge pump 'gotcha'

I thought your answer in Ask Silicon Chip, March 2019 (page 102) about matching a solar panel to a bilge pump was good, but there is 'gotcha' which never shows up in testing.

Imagine that the float switch closes in the night. The sun rises exceptionally slowly, and there is no 'kick' or switch-on impulse for the motor. When the panel is well illuminated, the panel short circuit current continues flowing through the same commutator segments, but the armature never rotates. It could burn the motor out.

The Alternative Technology Association used to sell a kit for this particular application which is now available from LEDsales (siliconchip.com.au/link/aapu).

You can see the circuit on that website, with a good explanation of how it operates. It is called a "Solar pumping maximiser". They have kits for various pump currents in 12V and 24V versions. I have no connection with the vendor other than as a satisfied customer.

Finally, Brendan Akhurst deserves a pay rise. He is on my wavelength, and I have enjoyed the banter about Joe Lucas – Poms learned to drink their beer warm because Lucas made the fridges!

Richard Elliott,
Majors Creek, NSW.

The times, they are a-changin'

Regarding your April editorial, as a lad, I attended a school in the 1950s. Every second Tuesday had a session of Army Cadets or Community Service. My Community Service group was one which took in "trade in" radios from retailers, refurbished them (mainly by replacing the electros) before they were distributed to pensioners who couldn't afford one.

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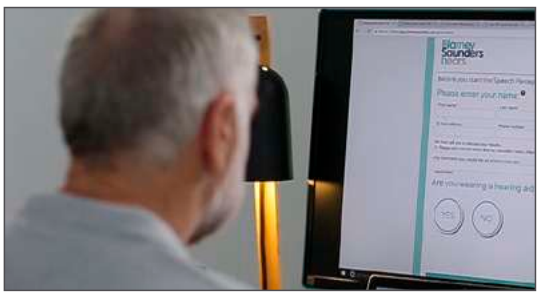

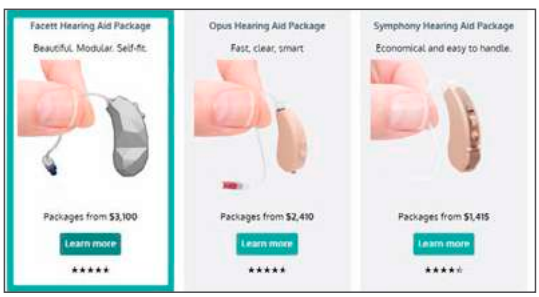

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They were all mains-powered sets and often required new power leads. Our work was entirely unsupervised, and we managed to avoid any casualties.

I also had to spend a year in the cadets. Before Camp, we were issued with a 1919 .303 rifle which I took home on the train. Security consisted of putting the bolt in my bag rather than in the rifle. Note that they didn't give us any ammo to take home.

There was a recent incident where the Melbourne rail loop was shut down for hours because someone thought a busker had a rifle bag rather than his instrument bag. Heavily armed police swarmed the railway station. While I believe the authorities had to do what they did, there is something to be said for "the good old days".

Geoff Champion,
Mount Dandenong, Vic.

Another request for multi-input audio switcher

I was very interested to read your excellent remote controlled preamp design presented in the last couple of issues. May I be selfish and suggest another project that could draw on parts of that design that would make my home life easier?

I do not have a five-channel home theatre set-up but instead, have a great stereo set-up in my lounge room that includes a slightly modified SC480 power amplifier. But I have many possible signal sources including DVD/SAC, Blu-ray, Rune streamer/DAC, TV, game console and even a cassette deck.

Changing between these requires a bit of fiddling with either the selector on my preamp and/or another dodgy four-way switch box. I have no problem with this, but it drives my family crazy! A standalone six-input remote selector based on that used in your preamp would be a godsend. If it were modular and scalable, I'm sure many would find uses for it.

It would also reduce the amount of eye rolling I get from my daughter. If you really wanted to go to town, control via a phone or tablet would be amazing, but I can imagine that would be a bridge too far.

Concerning the complaint to NSW Fair Trading about your mains-powered projects (mentioned in your April editorial), if they pull you up for this, then I hope they do the same to hardware stores. Take a stroll through their electrical aisles. Surely they are also promoting mains powered 'projects' with all the stuff they sell to DIYers that can only be used by connection to the mains.

At least you put lots of effort into illustrating correct techniques and warning of the dangers in your projects. I'm a long time reader of your unique magazine and look forward to every issue.

Kim Windsor,
Newport, Vic.

Response: as mentioned on page 6, we are planning to offer a six-way input switcher which can be used in combination with the new preamp. Note though that if you want to switch video too, especially HDMI, you will probably need to use a commercial input switcher. They are pretty cheap, but it would be quite hard to incorporate HDMI switching in a DIY project.

Thanks for pointing out DDS module flaw

I want to congratulate Ross Herbert of WA on tracking down the cause of the DDS Signal Generator/IF Alignment project (September 2017; siliconchip.com.au/Article/10799) failing to operate as designed (March 2019, Mailbag page 13).

The resistor array in my kit measured 1kΩ and replacing it with short lengths of wire effected an immediate response. I'm now using the DDS IF Alignment unit to adjust a 1946 radio.

Robert Forbes,
Forest Hill, Vic.

Medical alarms and the NBN

"Making emergency calls post-NBN" in the March issue of Silicon Chip (Mailbag, page 10) really caught my attention.

For about 17 years I co-owned the VitalCall Medical Alarm business. I am currently the Chair of Personal Emergency Response Services Limited (PERSL), an industry association representing the interests of professionally-monitored medical alarm suppliers, service providers, and their clients.

Before the NBN, the PSTN was able to operate for long periods during a power failure and was extremely reliable, with a quoted 99.9% uptime. It reliably supported a wide range of socially important services such as security alarms, fire alarms, lift alarms and medical alarms.

The first version of the NBN, the Fibre to the Home (FTTH) system, could be fitted with a battery back-up power supply giving about 8-12 hours battery operation, and was also considered reliable.

However, that all changed with the introduction of the Fibre to the Node (FTTN) and more recently the Hybrid Fibre Coax (HFC) systems.

These two NBN systems use upstream equipment to convert from the fibre network to either the customers' copper or coax access technology, and that equipment does not have battery back-up.

The latest system, Fibre to the Curb (FTTC), is a much better option as the node in the street is back-powered from the customer's premises, and this power could be battery-backed. Alas, it has all come too late and FTTN and HFC will have the majority of customers.

Since the introduction of the NBN, our industry group has been working with NBN Co and the Retail Service Providers to ensure a smooth and uninterrupted transition for professionally monitored medical alarm users to the NBN. A federally funded scheme was introduced to swap-over all PSTN based monitored medical alarms in NBN service areas with 3G wireless alarms.

It could be argued that moving to 3G wireless was merely swapping one set of risks for another, so most professionally-monitored medical alarms now have the capacity for dual connectivity. They can make emergency calls over both the NBN voice service and the 3G mobile wireless service.

Clients with professionally 24/7 monitored medical alarms can be confident that their alarm service is reliable and will always be professionally maintained.

The situation with non-monitored medical alarms is more confusing. Because non-monitored medical alarms rely on family and friends to receive all the calls for assistance, and also to test and maintain the alarm equipment, they do not have the same degree of professional support.

Recently, the federally funded alarm upgrade scheme was extended to non-monitored medical alarms, and some users with PSTN based non-monitored medical alarms have chosen to upgrade to a 3G wireless alarm at a lower cost.

There are also some 3G alarm pendants/trackers being sold, which are basically a mobile phone module and a GPS receiver in a small housing. These alarms have the advantage of working outside the home and can show the location of a person needing help on a responder's smartphone. They also make voice calls, so the responder can speak directly to the person needing help.

Their disadvantage is that they rely solely on mobile phone network coverage, they need to be recharged every day or two, and again, they do not have the same degree of support as a monitored alarm.

Note that some mobile devices, including some new 4G non-monitored medical alarms, are being marketed as "future proof" 4G devices, even though they can't make voice calls over Voice over LTE (VoLTE). Such 4G devices can only make voice calls over 3G and, even though they are marketed as 4G devices, their voice function will not work when the 3G networks are closed down.

If you, or a member of your family, are considering purchasing a medical alarm I strongly suggest you take some time to research the options and consider the importance of a professionally monitored and maintained service.

Phil Wait,
Neutral Bay, NSW.

Response: we still don't understand how 3G/4G provides sufficient redundancy to be a useful backup for the NBN for safety-of-life systems, as it seems that both can go down within hours of a widespread power failure. And extended power failures are a fairly common result of natural disasters like fires, floods and cyclones.

Shaded pole motor speed controller thumbs up

I've just built the fan speed controller for shaded pole motors from the March 2014 issue.

Over time I had tried different 'phase-controlled' speed controllers in Diac or Triac form, all of which made the motor growl at lower speeds.

The concept of using a FET as a variable resistor inside a rectifier to maintain AC in the external circuit was inspired. At last, I have a speed controller that can make a fan produce a gentle breeze without any motor noise. Thanks, SILICON CHIP!

E. McAndrew,
Capel, WA. SC

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SILICON CHIP visited the Australian International Airshow and Aerospace and Defence Exposition, also known as the Avalon Airshow, to take a look at the latest aerospace technology. This is a major international show and attracts the largest aerospace corporations from all over the world, as well as some smaller ones. It's held every two years at Avalon Airport, near Geelong in Victoria.

This article concentrates on new developments in aerospace technology. We aren't going to cover any of the technology already described in our previous articles on the Avalon Airshow, in the May 2013 (siliconchip.com.au/Article/3789) and May 2015 (siliconchip.com.au/Article/8550) issues.

In those previous articles, we covered modern aircraft operating in Australian, including the RAAF C-17 Globemaster III, the Heron, E-7A Wedgetail, KC-30A, MQ-4C or many other interesting aircraft and related platforms.

So without further ado, let's now take a look at what was new at the Avalon Airshow this year. Fig.1 shows a map of the exhibits.

Boeing "Loyal Wingman"

The Loyal Wingman is an Australian-developed, artificial intelligence based stealthy combat drone under development by Boeing in Brisbane, in conjunction with the Royal Australian Air Force (RAAF) – see Fig.2.

The unexpected unveiling of this system at the show caused quite a stir among industry personnel.

This is the first high-performance military aircraft Australia has made since World War II. The Wingman is designed to fly along with other manned aircraft such as the RAAF Boeing E-7A Wedgetail airborne early warning and control (AWACS) aircraft (see SILICON CHIP May 2013) or the RAAF Boeing P-8A Poseidon maritime patrol aircraft (see SILICON CHIP May 2015).

It can also fly alongside the RAAF F/A-18F Super Hornet or F-35A on combat missions, where its role would be to take on higher-risk intelligence-gathering tasks, surveillance and reconnaissance missions in enemy airspace and possibly also deliver missiles or bombs.

At 11.7m long and with a range of 2000 nautical miles (3700km), it is expected to cost less than a manned fighter. Boeing is spending an undisclosed amount of money on the project and the Australian Government has provided $40 million. The first prototype flight is expected in 2020.

See the videos titled *"Boeing unveils its 38ft long autonomous 'Loyal Wingman' drone"* via siliconchip.com.au/link/aaoj and *"Boeing's 'Loyal Wingman' drone | What the Future"* at: siliconchip.com.au/link/aaok

The F-35A and RAAF Plan Jericho

The Air Force is undergoing rapid change due to new technology, including the new F-35A fighter aircraft which Australia is purchasing (Figs.3 & 4). It is regarded as a "fifth generation" aircraft. The previous generations were as follows.

- The first generation of jet fighters were the subsonic jets which first took flight in the mid-40s (towards the end of WW2 or just after), such as the Gloster Meteor and North American F-86 Saber.
- Second generation fighter jets were unveiled in the mid-50s to early 60s; they had afterburning turbojets; for example, the Dassault Mirage.
- The third generation were aircraft from the mid-60s to early 70s, with improved manoeuverability, ground attack capabilities and guided missiles. This includes the McDonnell

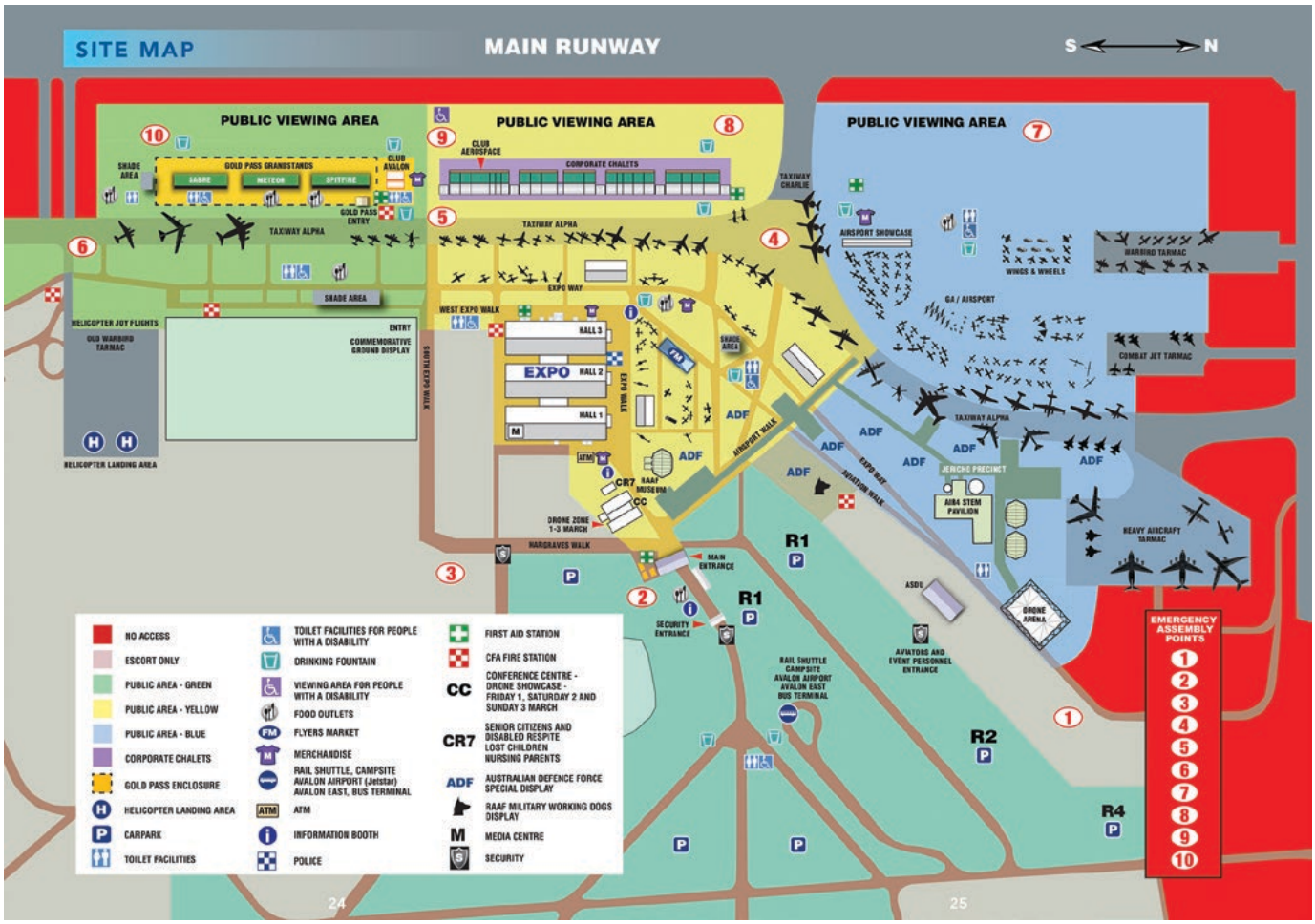

Fig.1: by any definition, the Avalon Airshow is BIG! This site map shows how spread out the airshow was, and how many aircraft were on display, from tiny to enormous.

Douglas F-4 Phantom II.

- The fourth generation took flight from the early 70s to the mid-90s, including multi-role aircraft with advanced avionics and weapons, such as the McDonnell Douglas F/A-18 Hornet.
- "Four-and-a-half" generation jets were built from the early 90s to mid-2000s, and were mostly modified fourth-generation aircraft with enhanced features such as improved radar and infrared signature management, helmet mounted sights, GPS guided weapons and highly integrated systems. This includes the McDonnell Douglas F/A-18 Super Hornet.
- Fifth generation aircraft have very low radar and infrared signatures (stealth capability), internal weapons bays, vastly improved situational awareness and a network-centric combat environment. This includes the Lockheed Martin F-35 Lightning II, which is just starting to enter service.

Fifth-generation fighters are part of "network-centric warfare", which is a military doctrine, originating in the USA in 1996. This seeks to translate information from superior sensors and communications into a military advan-

Fig.2: the Australian-developed Boeing Loyal Wingman autonomous fighter jet on display.

Fig.3: a recently delivered RAAF F-35A Lightning II flying near RAAF Base Amberley in Queensland. It is a fifth-generation fighter jet and an essential element of Plan Jericho.

Fig.4: an Australian F-35A on the ground.

tage by the use of computer networking to distribute that information to one's own geographically dispersed forces.

The network-centric combat environment of the fifth generation F-35A and other current generation platforms means that the entire Air Force (and indeed the entire military) must be optimised to take full advantage of this, which culminates with Plan Jericho.

The Air Force was extensively promoting this plan at the Avalon airshow. Its purpose is to "protect Australia from technologically sophisticated and rapidly morphing threats".

It will use "augmented intelligence" to shift the Air Force "from one that uses people to operate machines and cooperate with other people, to a force in which people and machines operate together".

This plan has four main prongs:

1) the use of autonomous processing, embedding machine processing throughout the force, to improve the speed and correctness of decisions that need to be made during combat
2) the use of advanced sensors, to detect and track enemy targets in difficult environments
3) a "combat cloud", to integrate and distribute resources from across the fifth generation force, to further enhance decision-making
4) human-machine augmentation, to optimise performance within an ethical, moral, and legal framework

You can read more about Plan Jericho via **siliconchip.com.au/link/aaol**

The RAAF EA-18G Growler

The RAAF had on display its EA-18G Growler. Australia has 11 of these, based at RAAF Base Amberley, 40km south-west of Brisbane (see Fig.5).

The Growler is an "electronic attack aircraft", designed to disrupt or deny enemy radar, sensors and communications. It can cause the enemy to receive false radar returns or to falsify other data. The Growler is based on the F/A-18F Super Hornet airframe and has electronic equipment mounted where the 20mm cannon would otherwise be, plus wing-tip mounted electronics pods.

Nine weapons stations remain available for weapons or additional electronics pods.

Further upgrades for the Growler are being developed for the US Navy, known as REAM (Reactive Electronic Attack Measures).

REAM will add machine learning and artificial intelligence to the Growler system, and these upgrades will probably be offered to the RAAF eventually.

In addition to its electronic warfare equipment, the Growler can carry the AGM-88 anti-radiation missiles, designed to home in on and destroy radar systems. Plus it can also carry AIM-120 medium-range air-to-air missiles and AIM-9X "Sidewinder" advanced short-

Fig.7: the Boeing Insitu ScanEagle unmanned aerial system, as used by the Royal Australian Navy.

Fig.8: a US Navy ScanEagle in flight.

Fig.5: an RAAF EA-18G "Wild Weasel" electronic attack aircraft. The pods contain electronic warfare equipment, such as radar and communications jammers. "Wild Weasel" refers to any type of aircraft tasked with destroying enemy radar and air defence systems.

Fig.6: the AOS Kelpie autonomous ground vehicle on the loading ramp of an RAAF C-17A Globemaster III cargo aircraft. The RAAF operates eight Globemasters, each with a cargo capacity of 77 tonnes. See SILICON CHIP, May 2013 for more details.

range air-to-air missiles, both for chasing off or shooting down enemy aircraft which threaten the Growler.

See the video titled *"RAAF Growler delivery complete, report"* via **siliconchip.com.au/link/aaom**

Kelpie Multi-purpose Autonomous Ground Vehicle

AOS is an Australian artificial intelligence company (**www.aosgrp.com**). The AOS Kelpie is an autonomous ground vehicle (AGV) that has been designed as part of the RAAF Plan Jericho (see Fig.6). It is an electrically-powered, off-road capable vehicle that can be used for applications such as patrolling a military base perimeter or delivery of matériel from a base to soldiers on the front lines.

It uses the iSight intelligent intruder tracking system, capable of autonomously tracking and classifying subjects of interest and applying facial recognition to humans.

It's a low-cost system, due to the use of standard components, and features a collision-avoidance system utilising LiDAR (Light Detection And Ranging) and an optional radar system.

It is capable of speeds up to 80km/h, can carry up to 100kg, has an onboard video camera to transmit live video and intelligent software agent technology with machine learning and machine vision.

Multiple software "agents" can be teamed up to enable multiple Kelpies to work with each other, and with humans. It's expected to be released in 2020.

ScanEagle

The Royal Australian Navy (RAN) had a Boeing Insitu ScanEagle unmanned aerial system on display (also used by the Australian Army) – see Figs.7 & 8.

It is a small, American-made remotely piloted aircraft that is in extensive use internationally. Its maximum takeoff weight is 22kg; it's 1.55-1.71m long (depending on configuration), has a 3.11m wingspan and an endurance of 12+ hours at an altitude of up to 16,800ft (5120m).

It is powered by a 28cc, two-stroke engine. It cruises at 50-60 knots (93-111km/h) with a top speed of 80 knots (148km/h). The payloads are modular, and a variety is available, such as electro-optical sensors, infrared sensors, a Visual Detection and Ranging (ViDAR) camera, Maritime Automatic Identification System (AIS) and Identification Friend or Foe (IFF) systems.

The RAN primarily uses the electro-optical and infrared payloads.

It is launched with a pneumatic (compressed air) launcher and recovered by a "Skyhook" retrieval system which uses a hook on the end of its wingtip to engage a rope hanging from a pole, the process being guided by high accuracy GPS.

Figs.9 & 10: the Schiebel Camcopter S-100 at the RAN display.

Additional Airshow Video Shortlinks

Here are some videos showing some of the sights of the show and other information.

- US Air Force Northrop Grumman RQ-4 Global Hawk unmanned aerial vehicle flying in and landing at Avalon. It flew in from Andersen Air Force Base in Hawaii, and this was the first time one landed at an airshow. See the videos titled *"Global Hawk Achieves Historic First at Avalon 2019"* via siliconchip.com.au/link/aapb and *"USAF Northrop Grumman RQ-4 Global Hawk UAV Arrival Into Avalon Airshow 2019"* via siliconchip.com.au/link/aapc
- Video of *"F 35 F 22 F 18 Flying In A Close Formation First Time Ever In Australia At Avalon Airshow 2019"* via siliconchip.com.au/link/aapd
- Air-to-air refuelling of RAAF F/A-18 by a KC-30A tanker, titled *"RAAF KC 30 Mid Air Refueling Two F 18 At Avalon Airshow 2019"* via siliconchip.com.au/link/aape
- RAAF F-35A demonstration, titled *"RAAF F 35 Power Pack Aerial Display At Avalon Airshow 2019"* via siliconchip.com.au/link/aapf
- Bird strike! USAF C-17 ingests a bird and aborts take off. See the video titled *"Bird Strike I USAF C17 Engine EXPLOSION on Takeoff I 2019 Avalon Airshow"* via siliconchip.com.au/link/aapg
- Video titled *"[4K] 2019 Avalon Airshow: F/A-18 Hornet, F-35A and F22 Raptor display (RAAF and USAF)"* via siliconchip.com.au/link/aaph
- Glider display, titled *"Johan Gustafsson SZD-59 'ACRO' Display Avalon Airshow 2019"* via siliconchip.com.au/link/aapi
- Avalon Trade Day 1 round up, titled *"Snapshot of Avalon Airshow action - Trade Day One"* via siliconchip.com.au/link/aapj
- Avalon Trade Day 2 round up, titled *"Avalon Airshow 2019 - Aircraft of Day Two"* via siliconchip.com.au/link/aapk
- USAF B-52 fly past, titled *"Boeing B-52 Stratofortress evening flypast - Avalon Airshow"* via siliconchip.com.au/link/aapl
- Australian industry participation in the F-35 Joint Strike Fighter Program, video via siliconchip.com.au/link/aapm
- An alternate view on the inadvisability of incorporating artificial intelligence in military platforms, titled *"Artificial Intelligence: it will kill us I Jay Tuck I TEDxHamburgSalon"* via siliconchip.com.au/link/aapn

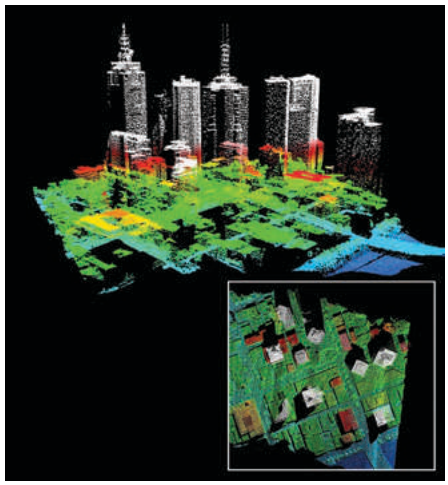

Fig.11: an airborne laser (LiDAR) scan of Melbourne from the RIEGL LMS-Q560.

You can view a video of the land-based launch and recovery of a ScanEagle by the Australian Army in Afghanistan, titled *"Insitu ScanEagle Launch And Capture"* via siliconchip.com.au/link/aaon

Schiebel Camcopter S-100

The RAN also had an Austrian-made Schiebel Camcopter S-100 on display. It is a helicopter-type unmanned aerial system used for shipborne intelligence, surveillance and reconnaissance – see Figs.9 & 10.

It's equipped with a Wescam MX-10MS multi-sensor multi-spectral imaging system, that can read the number plate of a car from 250m away and it also has night-vision capabilities.

The S-100 has a payload capacity of 50kg, is 3.1m long and 1.2m wide with a main rotor diameter of 3.4m. It weighs 110kg empty and has a maximum take-off weight of 200kg, 120 knot (222km/h) top speed and a cruise speed of 100 knots (185km/h) with an endurance of 6 hours and ceiling of 18,000ft (5500m).

The RAN unit has a heavy-fuel capable engine of unknown specifications, but the gasoline-powered versions use a 41kW Wankel rotary engine.

The RAN engine uses JP-5 low flash-point heavy fuel (kerosene-based), which is typically used as an aviation fuel on navy vessels and is safer than gasoline.

This engine can also run on JP-8 (also kerosene based, but more similar to diesel) and Jet A-1, the civilian equivalent of JP-8.

See the videos titled *"Schiebel CAMCOPTER S-100 - Royal Australian Navy Trials"* via siliconchip.com.au/link/aaoo and *"Schiebel CAMCOPTER S-100 - Heavy Fuel Engine"* via siliconchip.com.au/link/aaop

Fig.12: the RIEGL VQ-1560i-DW airborne LiDAR scanning system uses two different wavelengths for enhanced information. It has primarily environmental applications.

RIEGL laser measurement

RIEGL (www.riegl.com) make a variety of laser-scanning systems that enable three-dimensional images of a variety of scenes to be built quickly from land-based or aerial platforms.

Applications include scanning archaeological sites, architectural sites, monitoring land movements (such as in landslide-prone areas or glacier areas), monitoring city developments, monitoring mining sites, monitoring earth moving works, monitoring growth and density of forests and many others – see Figs.11 & 12.

Event-based Neuromorphic Space Imaging (Astrosite)

Neuromorphic imaging, as the name implies, is an imaging system modelled upon how the human eyes and brain register images.

The human eye tends only to notice changes in images rather than reacquire a whole new image each time; to do so would be wasteful of mental resources (or computational resources in this case).

Western Sydney University's International Centre for Neuromorphic Systems (ICNS), in conjunction with RAAF's Plan Jericho and Defence Science and Technology (DST) group, has developed Astrosite, a camera system that registers only changes in an image, just like the human eye and brain (see Fig.13).

It does this in hardware rather than

Fig.13: the Neuromorphic imaging system, Astrosite, aimed at the sky.

Fig.14: the Phoenix Jet target drone.

in software and is thus far more computationally efficient, because only changes in the image are sent as data. Such a system could be used for looking for astronomical events such as meteorites, monitoring satellite or space debris or aircraft movements or indeed anywhere where the subject of interest changes against a mostly static background.

All pixels in the camera operate independently of each other, so it has a high dynamic range and objects in space can be tracked even during the day. See the video via siliconchip.com.au/link/aaoq

Phoenix Jet

The Phoenix Jet is produced by the Australian company Air Affairs Australia (www.airaffairs.com.au). It is an unmanned aerial vehicle (UAV) target drone, used as a training aid for military personnel, as a realistic target for guns or other air defence systems (Fig.14).

It can be recovered via parachute for reuse, or it can be destroyed, depending on what the training exercise requires. Typically, it is flown on several training missions where it can be recovered before the more expensive exercise of destruction is undertaken.

It has an endurance of 60 minutes, can fly at a speed in excess of 330 knots (610km/h), has a range of 100km, a maximum altitude of 6000m (19,700ft), a maximum launch weight of 66kg, an internal payload (such as flares) of up to 3.5kg, a jet engine with 40kg thrust and is launched by a catapult (see Fig.15).

It can be augmented with a Luneberg lens to increase its radar cross section (making it easier for air defence radars to pick up), an IFF (identification friend or foe) transponder, and smoke, infrared and acoustic emitters. The aircraft is 2.4m long, 2.2m wide and 740mm tall. See the video titled *"Air Affairs Australia"* via siliconchip.com.au/link/aaor

Titomic Kinetic Fusion

Titomic (www.titomic.com) is an Australian company that specialises in additive manufacturing. It has exclusive rights to a CSIRO-developed process known as Kinetic Fusion, which involves the cold-gas spraying of titanium or titanium alloy onto a scaffold (which can be later removed) to make components without size or shape limitations (Fig.16).

Titanium is usually very difficult and expensive to machine, but this process avoids that. It has advantages over conventional 3D printing of metals (including titanium) because the particles are accelerated and fuse by collision, a mechanical process, rather than with heat which means there are no problems with oxidation and therefore no controlled atmosphere is needed.

Also, the components are fully formed; therefore, there is no weakness created by bending during fabrication. Dissimilar metals can also be fused. Very high build rates are possible.

The Joint Strike Missile (JSM)

The Joint Strike Missile is a multi-role version of the Naval Strike Missile developed by the Norwegian company Kongsberg Defence & Aerospace (www.kongsberg.com/en/kds) – see Fig.17. It is a fifth-generation missile, designed for internal carriage in the F-35A and F-35C jets for anti-ship and land attack missions, as well as for external carriage on other aerial platforms.

According to the manufacturer, it has high levels of survivability against anti-missile threats, an extremely low radar cross-section (stealth), extreme sea skimming ability, high lethality and it features autonomous target recognition. Two JSMs can be carried internally in the F-35 with more externally (with reduced stealth).

The project to adapt the missile to the F-35 is being funded by Norway and Australia. Australia is also funding development of a new seeker for the missile, by BAE Systems Australia.

Fig.15 (left): the Phoenix Jet on its catapult launcher.

Fig.16 (right): components produced by the Titomic Kinetic Fusion process.

Fig.17: a model of the intermediate-range Joint Strike Missile, two of which fit in the F-35A's internal weapons bays.

Fig.18: the Amazon Bot in its natural habitat, the Amazon jungle.

The missile uses an infrared imager to identify targets, but the new seeker will add an ability to track targets based on their RF signature as well.

The missile weighs 370kg with a 120kg warhead, uses an inertial guidance system, a laser gyroscope and GPS for navigation, has a range of greater than 150 nautical miles (277km); is 3.7m long and is powered by a solid rocket booster and a Microturbo TRI-40 turbojet.

See the videos titled *"NEW ADVANCED MISSILE for F-35 Joint Strike Missile JSM to defeat S-500"* via **siliconchip.com.au/link/aaos** and *"NSM - JSM Naval Strike Missile & Joint Strike Missile"* via **siliconchip.com.au/link/aaot**

Australian Space Agency

The recently formed (1st July 2018) Australian Space Agency (**siliconchip.com.au/link/aaou**) was present to publicise their role. The agency defines its role as follows:

"Providing national policy and strategic advice on the civil space sector; coordinating Australia's domestic civil space sector activities; supporting the growth of Australia's space industry and the use of space across the broader economy; leading international civil space engagement; administering space activities legislation and delivering on our international obligations; inspiring the Australian community and the next generation of space entrepreneurs."

SILICON CHIP readers will recall that Australia's first satellite, WRESAT, was launched in 1967. This space agency has now finally been formed, over half a century later! See the article on WRESAT in SILICON CHIP, October 2017 for more details (**siliconchip.com.au/Article/10822**).

Amazon Bot

Amazon Bot was an experimental hexapod robot developed by the CSIRO, designed to traverse terrain with its six legs that a wheeled robot could not (see Fig.18). It was also designed to be field-deployable and easily transported by one person; a rarity for most robots. It was tested in the Amazon as part of an international biodiversity project.

It used a laser-scanning system and camera to "see" and to create a detailed map of its environment. It was lost in transit back from the Amazon but work is underway to create new, more advanced robots that work with others, to explore underground environments such as caves.

See the video titled *"Data61 in the Amazon - a highlights reel"* via **siliconchip.com.au/link/aaov**

Rafael Drone Dome

Playing on the name of the highly successful Iron Dome, Israel's Rafael (**www.rafael.co.il**) has developed Drone Dome to counter enemy or terrorist drones, especially weaponised consumer drones (see Fig.19).

Terrorists have been known to use commercially-available consumer drones such as the DJI Phantom, and this system can neutralise those by either a "soft kill" or a "hard kill".

A soft kill is where the communication link to the operator, and possibly the GPS navigation signal, is jammed. If the drone is autonomous and this is not possible, then a hard kill is required, and this is effected by a powerful, weapons-grade laser (Fig.20).

The system detects the hostile drone with a radar and camera and can detect a target as small as 0.002m^2 at a distance of 3.5km. The system operator determines whether to destroy a hostile drone by soft or hard kill techniques. The entire system can be mounted on a

Fig.19 (left): Rafael's Drone Dome system can detect a drone up to 3.5km away. The system's radar does not rotate, but up to four radars can be combined for 360° coverage. It also has an optical sensor, a passive RF sensor and a jammer unit, plus a laser and a control centre with a single operator.

Fig.20 (right): Drone Dome's laser system for "hard kills".

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Fig.21: Drone Dome in a mobile application with four radar units, for 360º coverage.

Fig.22: the giant Freespace drone racing course in Barcelona.

vehicle if necessary (see Fig.21).

Other counter-drone systems exist, but almost none of these have the hard kill capability of Drone Dome. Another counter-drone system with hard kill capability is the Israeli General Robotics Pitbull AD (siliconchip.com.au/link/aaow) which uses a 5.56mm or 7.62mm machine gun to destroy drones and has other capabilities as well.

See the videos titled *"Rafael 'Drone Dome'"* via siliconchip.com.au/link/aaox (showing the destruction of a drone with the laser), *"Rafael's Horowitz: Drone Dome's Light Beam Helps It Quickly Defeat Long-Range Threats"* via siliconchip.com.au/link/aaoy (an interview) and *"Drone Dome 360° airspace defence against hostile drones"* via siliconchip.com.au/link/aaoz

Iron Dome

Rafael (www.rafael.co.il) had other offerings on display, including Iron Dome, which is a missile system designed to intercept and destroy incoming enemy rockets and artillery shells (Fig.25).

It has an operating range of 4-70km. In military parlance, it is known as a C-RAM system for Counter Rocket, Artillery and Mortar.

Iron Dome is combat-proven with over 1500 successful interceptions since it was introduced in 2011.

It is the only such combat-proven system in operation in the world. Its missiles are guided toward an airborne threat and they explode in its vicinity, to detonate the incoming warhead outside the defended area.

During flight, the Iron Dome interceptor receives trajectory updates from a Battle Management Centre via a data link. It is designed only to intercept threats heading toward the defended area, as it is pointless intercepting a threat that will land in an unoccupied location.

See the videos via siliconchip.com.au/link/aap0 and siliconchip.com.au/link/aap1 C-Dome is a sea-based variant of the Iron Dome designed to protect ships and other maritime assets.

Iron Dome is part of a multi-level air defence system being developed or in operation, which combines it with the following additional systems:

- Iron Beam, a defensive laser weapon designed to shoot down short-range rockets, artillery, and mortars which are too small or too close for Iron Dome, with a range of up to 7km
- Barak 8, jointly developed with India, which is a point-defence system which can defend against any airborne threat such as aircraft, helicopters, anti-ship missiles, UAVs and ballistic missiles with a range of 500m to 100km
- the Arrow 2 anti-ballistic missile (ABM) system with a range of 90km-150km
- David's Sling, which is designed to intercept enemy planes, drones, tactical ballistic missiles, medium to long-range rockets and cruise missiles at ranges of 40-300km
- the Arrow 3 ABM with a range thought to be about 2400km

Fig.25 (left): an Iron Dome missile on display at the Airshow. It is used for intercepting inbound rockets, artillery and mortar rounds.

Freespace giant drone racing

Freespace Drone Racing (https://freespaceracing.com) is an Australian

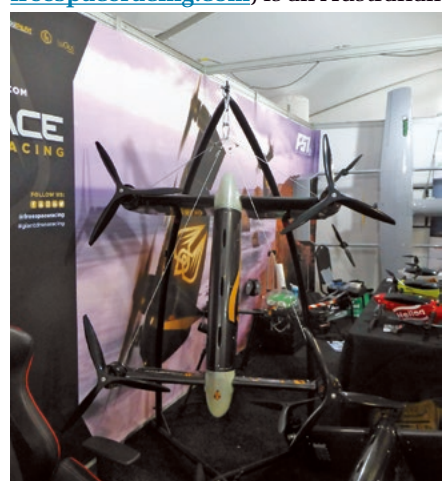

Fig.26 (right): a Freespace FS1 giant racing drone. It is 1.3m tall and weighs over 25kg, with a top speed of 220km/h. The drone is shown in its flight orientation, with its wings aligned with the direction of airflow from the rotors.

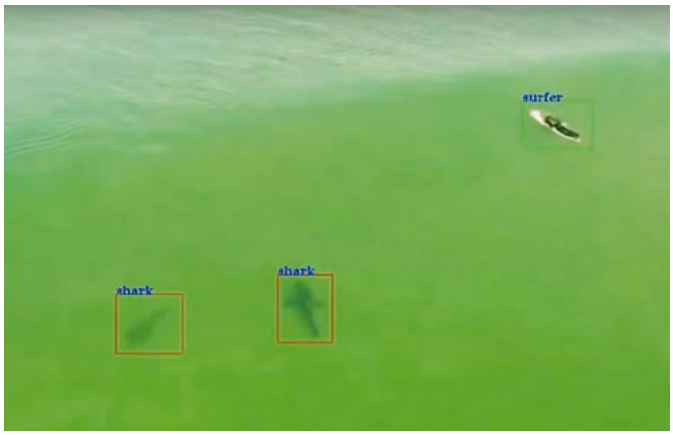

Fig.23: a video screen grab showing the automatic identification of sharks and a surfer. The system can distinguish between sharks, whales and dolphins, even though the shapes may be quite indistinct.

Fig.24: the Little Ripper is a hexacopter which can carry a rescue pod, slung beneath it towards the rear.

company that is involved in developing the sport of drone racing and advancing it to a higher level. They have developed racing drones that are of a "giant" size, making them suitable for commercial sponsors, due to the availability of easily-seen advertising space on the drone bodies.

The large size also makes them much more visible to viewers. Anyone who has watched a conventional drone race will realise that they can be tough to see due to their small size and high speed.

Freespace have developed a racing "experience" geared to Millenials and Generation Z and have also entered into an agreement with FAI, the World Air Sports Federation, the international governing body for air sports and also Greyhound Clubs Australia to utilise their tracks for racing (Fig.22).

The Freespace-developed FS500-class drone is 500mm long, weighs under 2kg, has a top speed of 120km/h and a 0-100km/h time under one second.

They are also developing the FS1 which is 1300mm long, weighs over 25kg, has a top speed of 220km/h and a 0-160km/h time under four seconds.

Giant drone racing is somewhat reminiscent of the pod races from the movie "Star Wars: The Phantom Menace". See the video titled *"Giant Drone Exhibition Race - FS500 - FAI 2018 BDWC F3U"* via **siliconchip.com.au/link/aap2**

Westpac Little Ripper Lifesaver

The Westpac Little Ripper Lifesaver (**https://thelittleripper.com.au**) is the name given to not one unmanned aerial vehicle (UAV) or drone but a suite of them, used for search, rescue and lifesaving operations.

SharkSpotter was developed with the University of Technology, Sydney (UTS) and uses artificial intelligence to detect sharks. A UAV flies around the protected area and if sharks are detected, it can hover over the location and emit an audible warning for swimmers to vacate the water. Sharks can be identified with an accuracy of 90% (see Fig.23).

The system can be fitted to a helicopter or hexacopter UAV (Fig.24) or any other type of UAV. See the videos titled *"Little Ripper Lifesaver Drones Spot Sharks Electronically"* via **siliconchip.com.au/link/aap3** and *"'Little Ripper' drone to spot sharks and save lives in Australia"* via **siliconchip.com.au/link/aap4**

Little Ripper Lifesavers can also be used to drop rescue packages, called "pods", to distressed persons.

Pods are specialised for marine, land or snow rescues and can contain items like an automatic external defibrillator, water activated personal floatation device, electromagnetic shark repellent or personal survival kits containing an EPIRB, water, thermal blanket, radio, first aid etc.

The world's first rescue with a UAV was at Lennox Head (NSW) in January 2018. See the video titled *"Westpac Little Ripper - Lennox Heads rescue"* via **siliconchip.com.au/link/aap5**

Two more videos on the Little Ripper can be seen via **siliconchip.com.au/link/aap6** and **siliconchip.com.au/link/aap7**

There are opportunities to become a Little Ripper Lifesaver pilot. See their website (link above) for details.

Monash UAS

Monash UAS is a student-run organisation at Monash University that designs, builds and competes with UAVs.

Fig.27: Opticor lightweight transparent armour from PPG Industries.

Fig.28: Farbod Torabi (L) and Lachlan Cunningham (R) from the Monash UAS team, with their highest-ranking UAV from the 2018 UAV Medical Express competition. The wings provide lift for forward flight while the four rotors allow for vertical takeoff and landing.

Fig.29: the RMIT UAS Research Team display, with the Black Kite on the right.

Fig.30 (above) and 31 (opposite): the Australian-developed HyperHalo petrol-powered drone. It can carry a payload of up to 10kg and has a four hour flight time,

They had on show their highest-scoring entry from the 2018 UAV Medical Express Challenge (**https://uavchallenge.org/**) – see Fig.28.

The mission was to "retrieve a blood sample from Outback Joe at his farm and in doing that they had to land within 10m of a visual target.

Their aircraft had to fly at least 12 nautical miles from the Base of operations to Joe's farm, and back (24 nautical miles in total, which is approximately 44.5km)."

You can follow the UAS team on Facebook at **www.facebook.com/MonashUAS/**

RMIT UAS Research Team

The RMIT UAS (unmanned aerial system) Research Team (**http://ruasrt.com**) is a multidisciplinary research team that conducts research into "the critical technical, operational, social and safety challenges facing the emerging UAS sector".

One of their offerings was the Black Kite, an all-weather UAS that can operate in harsh environments including winds up to 40 knots (74km/h), is suitable for use in a maritime environment, has a 3.5kg payload capacity, a 25 minute flight time, 3.5km range, is capable of ditching in water and has a dash speed of up to 50 knots (93km/h) – see Fig.29.

Its standard payloads include a UAV Vision CM132A imaging system with 30x optical zoom (3x optical zoom for infrared) and a two-axis gimbal; and a Foxtech Seeker-30 imaging system with 30x optical zoom and a three-axis gimbal.

HyperHalo drone

The HyperHalo (**www.hyperhalo.com**) is an Australian-developed petrol-powered drone that can carry a payload of up to 10kg and has a four hour flight time, or longer with a lighter payload. It weighs 13.5kg empty, has an engine capacity of 26-32cc and a rotor width of about 2m (see Figs.30 & 31).

In addition to its uniquely long endurance for a vertical lift drone, it has other features such as virtual thrust vectoring due to its three variable pitch "thrust rotors", one of which is located beneath each of the three variable pitch main rotors (Fig.32). This gives unprecedented control of the vehicle, and it can fly fast in forward flight and is very stable in adverse wind conditions.

It has three flight modes:

- **aeroplane mode**, where it operates similarly to an aircraft with bank, roll, pitch and yaw authority;
- **helicopter mode**, where it can operate with pirouette and high-torque yaw authority; and
- **UFO mode**, where the drone operates in a combination of aeroplane mode and helicopter mode, with the addition of virtual thrust vectoring.

In the event of an engine failure, the drone will auto-rotate to land like

Fig.33 (left): a space suit, as currently used on the International Space Station.

Fig.34 (right): the Generation III combat helmet.

Fig.32 (right): a close-up view of the HyperHalo rotor mechanism.

a traditional helicopter; a regular vertical-lift drone without variable pitch rotors cannot do this.

Spacesuit

A NASA space suit or "Enhanced Extravehicular Mobility Unit" was on display at the Collins Aerospace stand, as used on the Space Shuttle and the International Space Station (Fig.33).

Each suit can protect against micrometeoroids travelling at up to 27,000km/h, temperatures between -156°C and 121°C, contains 91m of coolant tubing and comprises 18,000 parts.

The suit is manufactured by ILC Dover and its life support systems by the Collins subsidiary of UTC Aerospace Systems.

Generation III combat helmet

The Smart Think company (https://thesmartthink.com) is an Australian/Singaporean venture to produce state-of-the-art defence products and is working with Deakin University's Institute for Frontier Materials (www.deakin.edu.au/ifm) and the Defence Materials Technology Centre (DMTC; www.dmtc.com.au) to produce a Generation III combat helmet for the military.

The helmet is offered in two different materials: UHMWPE (ultra-high molecular weight polyethylene) or aramid (commonly known by the tradename Kevlar) – see Fig.34.

The key advantage of these helmets is that they can be manufactured in an automated fashion, without splicing the fibre layers, which is usually required in highly curved composites made of these materials, because they are so stiff and difficult to form at tight radii.

The ability to manufacture with single sheets of reinforcement results in significant reductions in weight, reduced deformation on impact and gives improvements in structural performance and quality control.

FORTIS exoskeleton

FORTIS is a passive (non-powered) exoskeleton device produced and sold by Lockheed Martin, designed to assist workers to handle heavy tools by transferring the load directly through the exoskeleton to the ground.

It works via a system of counterweights to keep the worker steady, and was initially designed for frontal loads only (Fig.35).

Lockheed Martin has partnered with the Institute for Intelligent Systems Research and Innovation (IISRI) at Deakin University to extend the capability of the device, to allow the carriage of large posterior loads such as oxygen tanks and heavy backpacks over 30kg for the mining industry, and in particular, diamond mining.

IISRI's research involves the design and fabrication of attachments via 3D printing and determining stress and strain distribution within them via computational methods.

This is followed by human performance analysis involving mobility assessment, load transfer and safety with techniques such as motion tracking, electromyography, biomechanics and electrocardiogram measurements.

Fig.35 (left): the FORTIS exoskeleton enables workers to hold heavy tools (up to 16kg) effortlessly and results in greatly reduced muscle fatigue. Deakin IISRI researchers are looking at ways to extend its capabilities.

Sikorsky–Boeing SB-1 Defiant helicopter

The Sikorsky–Boeing SB-1 Defiant helicopter was presented at the airshow as a scale model. It is a twin-

Fig.36 (right): a model of the SB-1 helicopter.

Fig.37: the Textron Systems Aerosonde HQ SUAS is visible at the top of this photo. It has four vertical lift rotors for vertical takeoff and landing, plus wings and a pusher prop for forward flight.

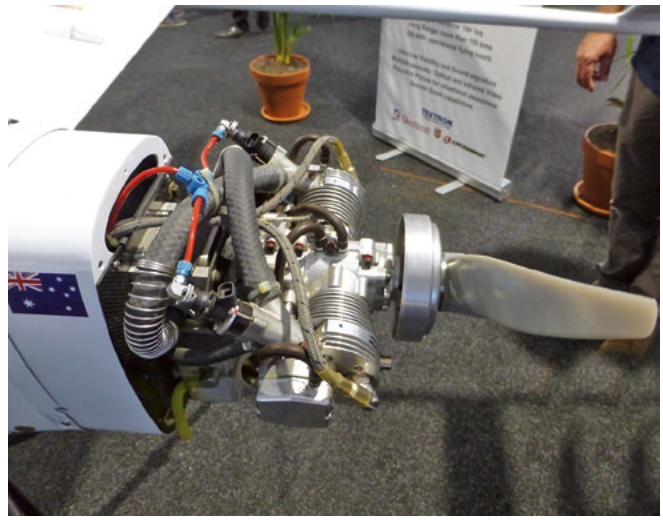

Fig.38: a close-up of the engine in the civilian version of Aerosonde.

rotor design with a pusher propeller. It is still under development – see Fig.36 and the video titled *"Sikorsky - Boeing Future Vertical Lift: The Way Forward"* avi: **siliconchip.com.au/link/aap8**

VTOL kit for Textron Aerosonde

Aerosonde Pty Ltd was an Australian-owned company, but it is now owned by Textron Systems in the USA (it still has Australian headquarters). The original Aerosonde company is now called Textron Systems Australia Pty Ltd.

It is offering a vertical take-off and landing (VTOL) kit to existing customers of their Aerosonde SUAS (small unmanned aerial system).

The platform becomes the Aerosonde HQ (Hybrid Quadrotor) after the addition of the conversion kit, which consists of twin booms, each with two vertical lift rotors and batteries (Fig.37).

Once the aircraft is in forward flight, the four rotors rotate to align with the flight direction, to minimise air resistance.

It has a Lycoming EL-005 75cc heavy fuel engine, allowing it to make a transition from vertical to forward flight at around 15-50m altitude and giving an endurance of eight hours with a 4.5kg payload, a service ceiling of 10,000ft (3000m) and a cruise speed of 45-65 knots (83-120km/h).

Aerosonde UAVs (not necessarily the HQ model) are used by many customers including the Australian Army, the US Marine Corps, US Air Force and US Special Operations Command. They also have commercial users such as the oil and gas industry (Fig.38).

Applications include day and night full-motion video capture, communications relay and special intelligence payloads; these can all be conducted on the one flight if necessary.

See the video titled *"Aerosonde HQ Advantages"* via **siliconchip.com.au/link/aap9**

Raytheon Coyote

The Raytheon Coyote is a low-cost, tube-launched expendable unmanned aerial system that is also capable of being launched in multiple units as a "swarm" (see Fig.39). This is known as LOCUST (LOw-Cost Uav Swarm Technology).

Coyote can be used to destroy other unmanned aerial systems using a seeker and warhead, or can be launched as a swarm for intelligence, surveillance and reconnaissance duties. It has also been used to acquire information about hurricanes.

See the video titled *"LOCUST Demo"* via **siliconchip.com.au/link/aapa**

Australian Army, Navy and Air Force drone racing teams

A drone racing program was hosted at the Airshow with teams from the Army, Navy and Air Force, plus a New Zealand military team as well as some others (Fig.40).

The events were held in a 10,000m^3 arena. Drone racing is authorised and even encouraged by the Australian Army and the first ever Military International Drone Racing Tournament (**www.army.gov.au/MIDRT**) was held in Sydney in October 2018. SC

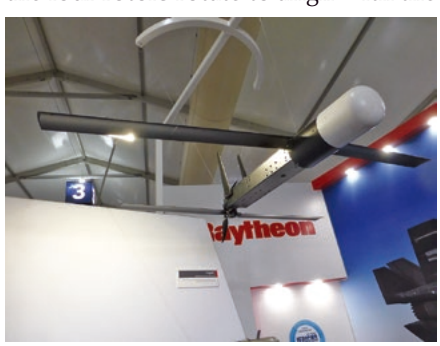

Fig.39 (left): the Raytheon Coyote, a low-cost, tube-launched expendable unmanned aerial system.

Fig.40 (right): a member of the Army drone racing team at the Drone Arena

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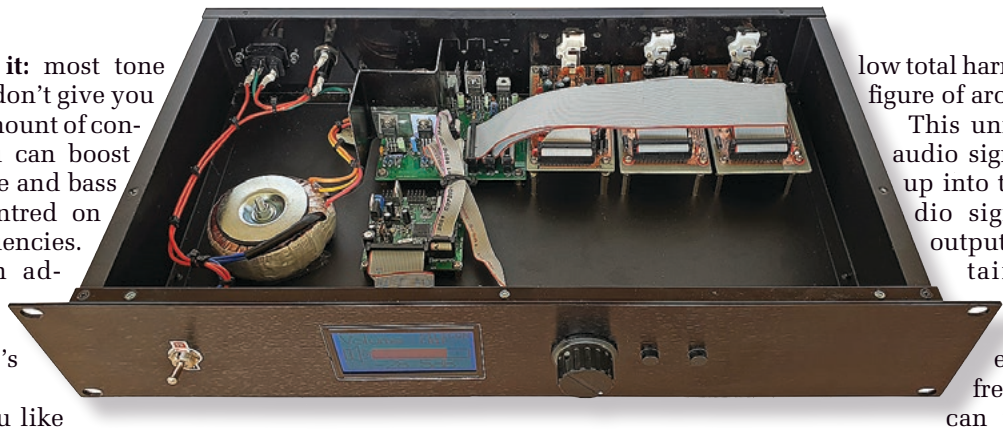
But wait: there's MORE!!

There's a wide range of audio processing tasks this project can handle. Yes, it uses DSP to provide an 8-channel parametric equaliser, so you can adjust frequency response to exactly the way YOU want it with really low distortion and noise. Or you can use it to "Biamplify" a pair of speakers. Or you can simply use it to experiment with any audio signal. And with its modular design it's even ready for future expansion.



Let's face it: most tone controls don't give you a huge amount of control! Sure, you can boost or cut the treble and bass – but only centred on particular frequencies. Sure, you can adjust the level between channels. But that's just about it.

Wouldn't you like to have TOTAL control over your sound system? You need this active crossover/DSP/Parametric Equaliser. It simply slots in between your sound source (no preamp required) and your amplifier (if your amp has tone controls, simply leave them "flat").

We've published active crossovers before (the latest in September & October 2017), and DSP-based projects before (October 2014), but this is the first time we've combined both concepts.

This is also the first time that we're publishing a digital signal processor that's truly high fidelity, as it has a very low total harmonic distortion figure of around 0.001%.

This unit takes a stereo audio signal and splits it up into two separate audio signals, with two output channels containing only the high frequencies and the other two, the low frequencies. These can then be fed to separate stereo amplifiers, with one amplifier driving the tweeters and the other driving the woofers. The signals combine in the air to give an accurate reproduction of the original audio signal.

This avoids the need for passive crossover circuitry, which can reduce sound quality, and allows for higher total power output, due to each amplifier only having to handle part of the audio signal. It can be tweaked to perfectly suit the drivers and cabinet used, as DSP allows for the crossover parameters to be set precisely and identically between the left and right channels.

Design by Phil Prosser . . . Words by Nicholas Vinen

Since the chip is already processing the digital audio data, we've also provided some parametric equalisation, so that you can modify the frequency response of the unit to compensate for any deficiencies in your drivers, cabinet, placement, room etc.

Basically, you can tweak the sound profile to be exactly the way you like it, and without any further degradation to the audio signal, since it's only converted from analog to digital and back to analog once, no matter how much additional processing is done in the digital domain.

Features & specifications

- Low distortion and noise: ~0.001% THD+N
- One stereo input, two stereo outputs (low/high), weird optional channel inversion
- Each pair of outputs can be crossed over using first, second or fourth-order digital filters
- Additional parametric equalisers: four, common to all outputs
- Optional high-pass filter for low-frequency outputs, to cut out subsonic frequencies
- Configurable delay for each channel, to compensate for driver offsets (up to 6.2m; 18ms)
- Individually configurable output inversion and attenuation settings
- Built-in volume control – no need to use a preamp
- Load and save setups to EEPROM
- Software written in Microchip C; could be adapted for other DSP uses (open source)

What the Active Crossover does

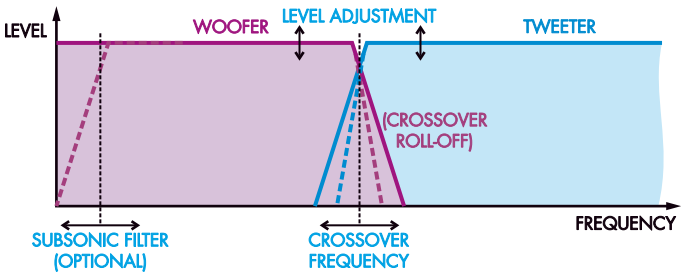


Fig.1: this two-way active crossover splits a signal with a spectrum covering the entire audible frequency range into two signals, one with the components above the crossover frequency and the other, the components below it. The optional woofer high-pass filter removes subsonic signals.

Fig.1 shows what the unit does. This shows the spectrum of an audio signal, with the frequency increasing left-to-right, from the lowest frequency that we can hear to the highest. The level of each component of this signal is shown in the vertical axis.

The blue area shows the signals which are extracted from the input to be sent onto the tweeter, while the mauve area shows those which go to the woofer. Signal components which fall in the crossover zone in the middle go to both outputs, although at reduced levels, so that they add up in such a way to give the original signal levels.

Since this active crossover is adjustable, you can set the crossover frequency to be at the ideal point for your loudspeaker. You can also adjust the steepness of the roll-off, as shown by the dotted lines, as different roll-off rates suit different situations.

There's also an optional subsonic filter, so that very low (inaudible) frequencies, or those which are too low for the woofer to reproduce, are eliminated and do not waste your amplifier power or possibly damage your woofer. Its frequency is also adjustable. (This is essential for vented, horn loaded and infinite baffle speakers).

The relative levels of the woofer and tweeter can also be adjusted, to compensate for differing driver efficiencies or amplifier gains, and although it isn't shown on the diagram, you can also delay one channel slightly relative to the other, to give proper 'time alignment'.

The four parametric equalisation channels are not shown in Fig.1, but essentially, each can be configured as either a high-pass or low-pass filter with adjustable stopband attenuation and corner frequency. This allows you to 'shelve' frequencies above or below a specific frequency, or between or outside a pair of frequencies, to shape the overall frequency response at all four outputs.

The Active Crossover is used as shown in Fig.2. It's connected between the stereo outputs of a preamp and four power amplifiers which power the four loudspeaker drivers independently.

Note that you don't need to use a preamplifier as this Active Crossover has a built-in volume control, so you can use it as a basic preamp too. In that case, the signal source is connected directly to the Active Crossover's inputs.

Why use an active crossover?

There are a few reasons why you may want to use an active crossover. Firstly, if you are building speakers from scratch, it's probably easier to use an active crossover than

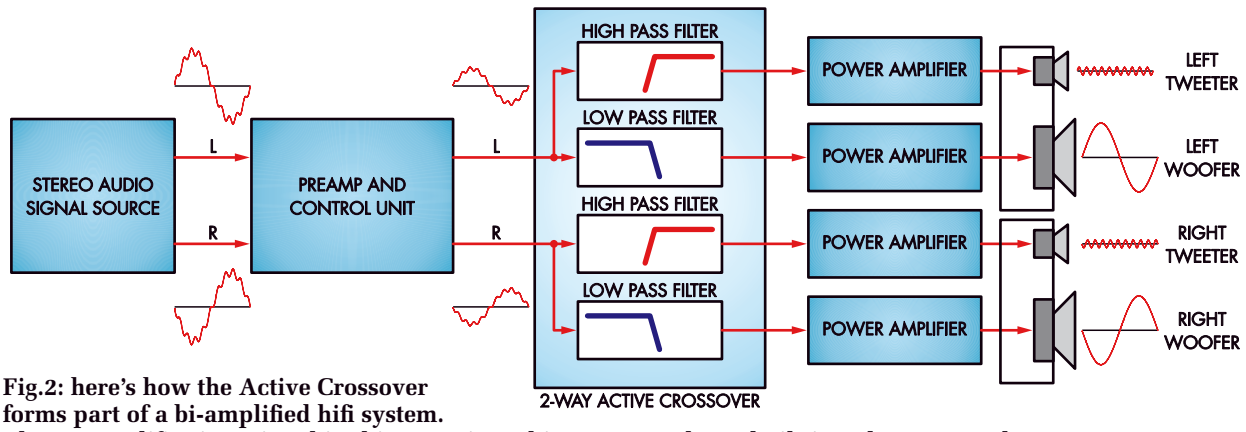


Fig.2: here's how the Active Crossover forms part of a bi-amplified hifi system. The preamplifier is optional in this case since this Crossover has a built-in volume control.

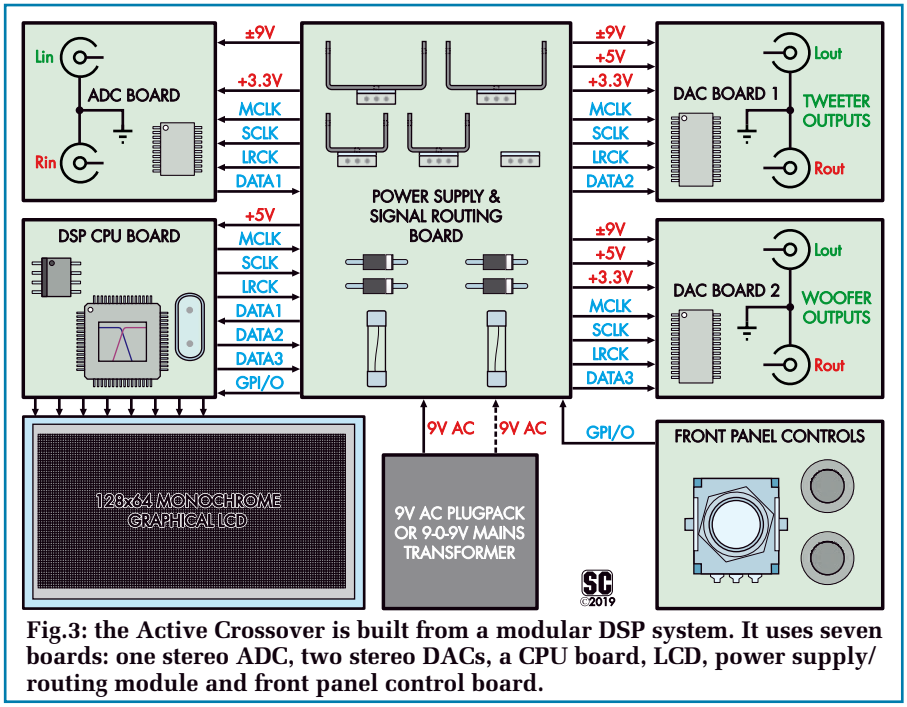


Fig.3: the Active Crossover is built from a modular DSP system. It uses seven boards: one stereo ADC, two stereo DACs, a CPU board, LCD, power supply/ routing module and front panel control board.

design a passive one, since you can easily experiment with it and change the crossover frequency/frequencies, relative amplitudes and so on until it sounds 'right'.

Also, if you're building a seriously powerful system with big amplifiers and big speakers, it's difficult to design a passive crossover to handle all that power.

Since an active crossover is connected before the amplifiers, and the amplifiers can then power the drivers with nothing in between, efficiency is maximised and you can deliver as much power as your amplifiers and drivers can handle.

Depending on the speaker design, you may also wind up with better overall sound quality using an active crossover than a passive one. Partly this is because it's hard to create a very 'steep' passive crossover, which crosses over across a small frequency range, but this is relatively easy to do with an active crossover.

Also, when using an active crossover, especially a digital one, because you have separate line-level signals for the tweeters and woofers, it is possible to compensate for the slightly different distance from each diaphragm to the listener by delaying one of the signals.

The exact delay required depends on the driver and cabinet design; it's tough to achieve perfect 'time alignment' mechanically, so being able to adjust this electronically is a boon.

Another advantage of an active crossover is that if you drive the system into clipping, usually this will be due to a huge bass signal. With a single amplifier for each of the left and right channels, that means that the treble signal will be clipped off entirely each time the bass signal hits one of the rails. That can sound really bad.

But with bi-amplification, even if you're clipping the bass signal, since most of the treble is going through a separate amplifier, it won't be affected. The result will still not be ideal, but won't sound anywhere near as bad; be thankful for small mercies!

Basically, except for the extra complexity that comes with the use of an active crossover, there are only benefits to this arrangement. It's much easier to adjust and tweak to give near-ideal sound quality, has minimal effect on signal quality or speaker power handling and can be adapted to any two-way loudspeaker system, as long as you can wire up each driver separately.

Modular design

This DSP Crossover is built by combining several different modules, each with a specific function. It was designed this way so that it could be reconfigured to do many different audio DSP tasks. In fact, with the same hardware but different software, it could be used for a variety of audio processing tasks such as echo/reverb/ effects, equalisation, delay and so on.

The basic configuration is shown in Fig.3. It uses seven main boards: one stereo analog-to-digital converter (ADC) board, two stereo digital-to-analog converter (DAC) boards, a microprocessor board, a power supply/ signal routing board and a front panel interface board. These are rounded out with a graphical LCD module for display, and a mains transformer to power it.

Interconnections are made between the boards with ribbon cables fitted with standard insulation displacement (IDC) connectors. This is a convenient and easy way to join boards where multiple signals and power need to be routed between them.

Audio signals are fed into the unit via the ADC board where they are converted to digital data. This data passes through the power supply/routing board and onto the microcontroller, which stores it in RAM before doing whatever processing is necessary.

It then feeds this data back out through a different set of pins, again as serial digital audio data, where it passes back through the routing board and onto one (or both) of the DAC modules. The DAC modules then convert these digital signals back into line-level analog signals which are available from two RCA connectors on the rear panel.

The microcontroller board is wired directly to the graphical LCD, so it can show the current status and provide the user interface, while the separate front panel control board connects to the micro via the routing board, allowing the user control over that interface.

The whole thing is powered from a 9V transformer, which could be a plugpack or mains type. If a mains transformer is used, it would generally be an 18V centre-tapped (9-0-9V) type, to give full-wave rectification.

But half-wave rectification, as would be the case with most plugpacks (as they usually have a single secondary winding), is good enough.

Circuit description

Let's start with the place where the audio signals enter the unit, the ADC board. The circuit diagram for this board is shown in Fig.4. It's built around an ultra high-performance ADC, the CS5361 (IC1), which has a dynamic range of 111dB and a typical THD+N figure of 0.001%.

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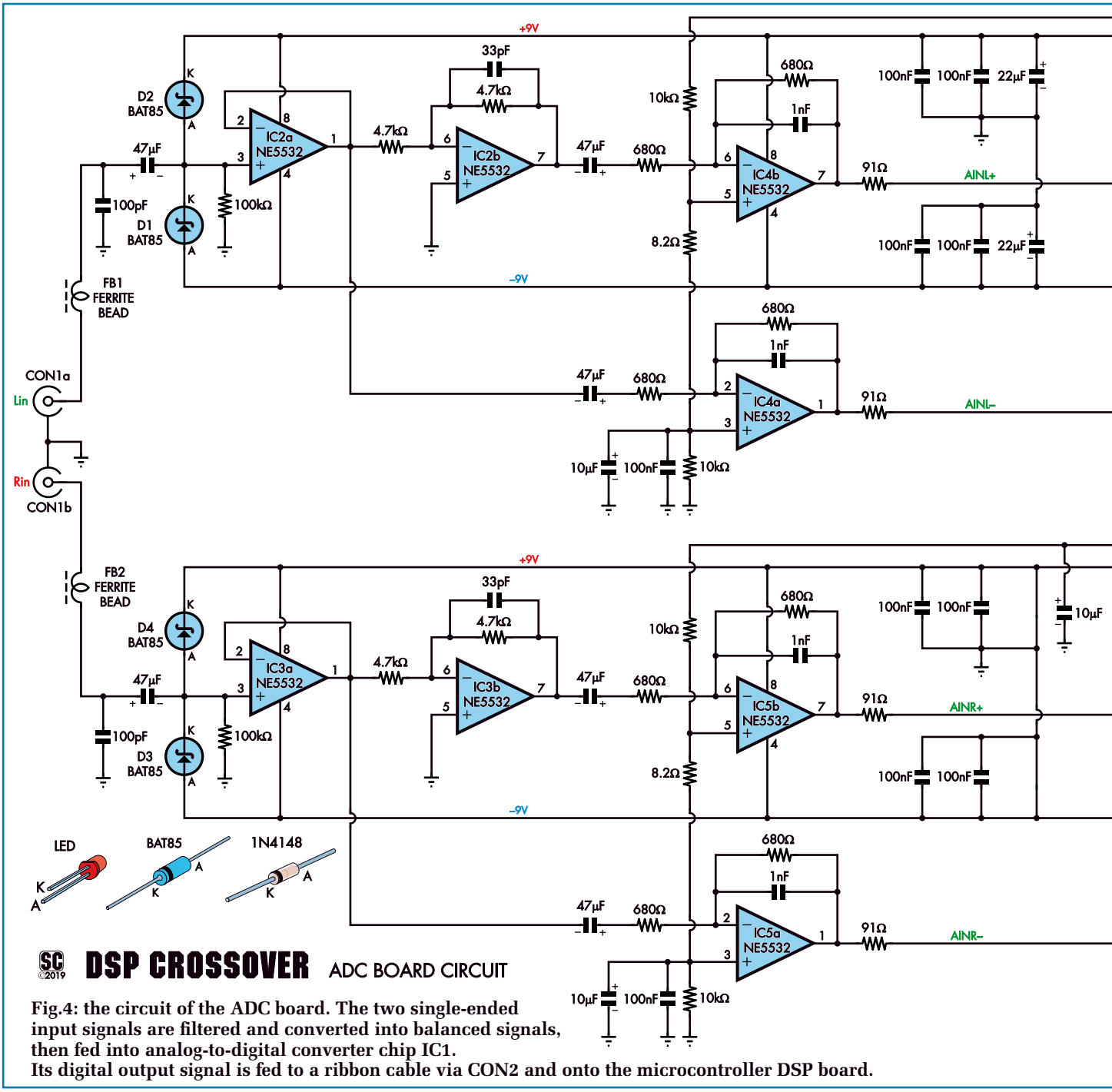


Fig.4: the circuit of the ADC board. The two single-ended input signals are filtered and converted into balanced signals, then fed into analog-to-digital converter chip IC1. Its digital output signal is fed to a ribbon cable via CON2 and onto the microcontroller DSP board.

the CS5381, which offers even lower distortion.

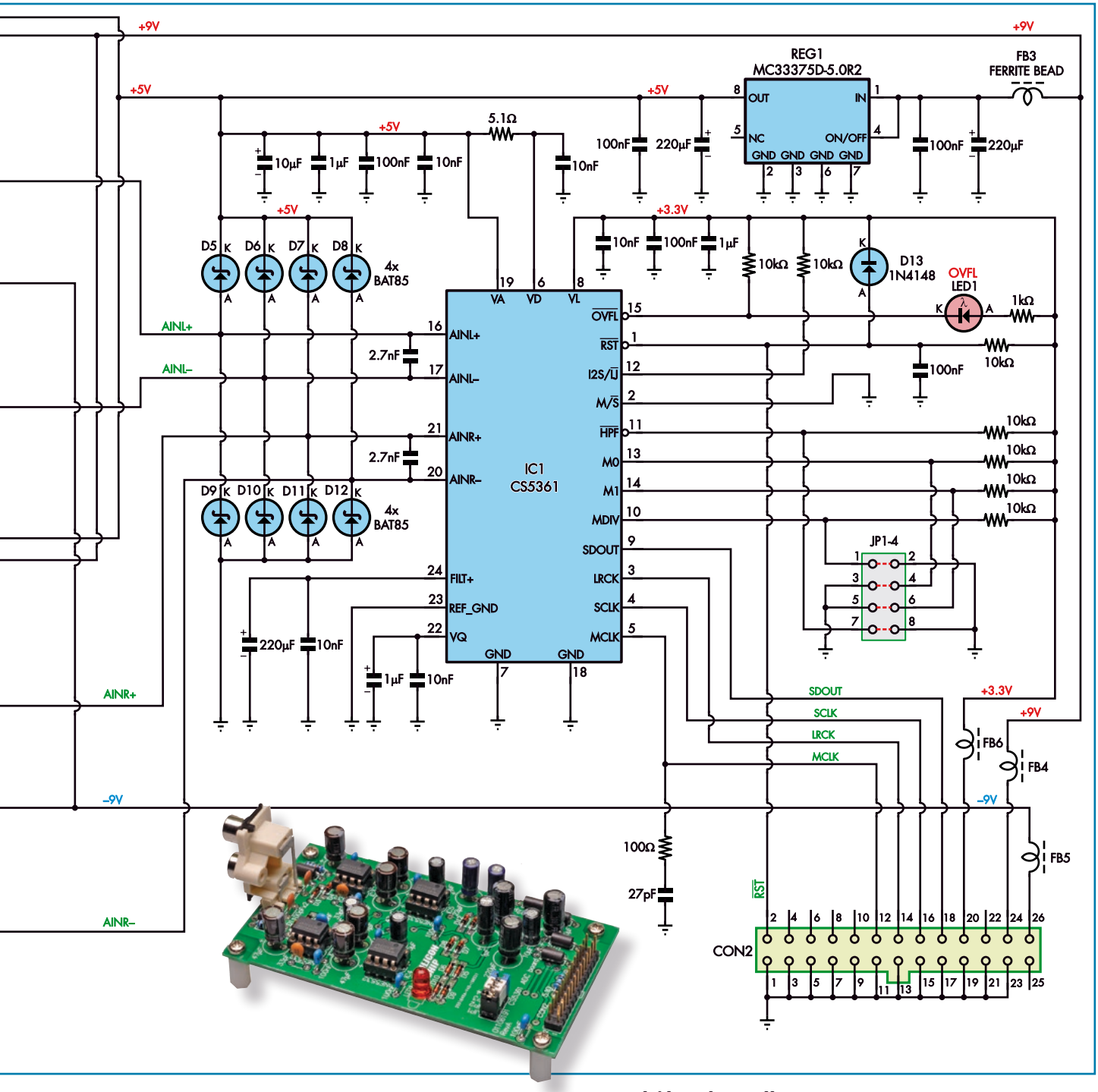
The stereo line-level audio signals are fed in via RCA sockets CON1a & CON1b. They pass through ferrite beads with 100pF capacitors to ground, both intended to remove any RF signals, either from the signal source or picked up in the connecting leads. As the two channels are processed identically before they reach the inputs of IC1, we'll just describe the left channel path.

The audio signal is then AC-coupled to non-inverting input pin 3 of op amp IC2a, an NE5532 low-noise, low-distortion device. Schottky diodes D1 and D2 prevent excessive voltages from being applied to this op amp, eg, inductive spikes generated by lightning or from incorrectly connected equipment. A 100kΩ resistor to ground provides a path for direct current to flow out of that input pin.

IC2a buffers the signal, providing a low-impedance source for the following filters. The signal is then fed to op amp IC2b, an inverting amplifier with a gain of -1, due to the use of two resistors of the same value in the feedback network.

A 33pF capacitor across the resistor between pins 7 (output) and 6 (inverting input) rolls off the ultrasonic frequency response to provide stability.

The reason for this inverting stage is that the ADC chip (IC1) is a differential design, so for both the left and right channel inputs, it expects two signals, one 180º out of phase with the other. The in-phase signal comes from the output (pin 7) of IC2b, while the out-of-phase signal is taken di-



rectly from the output (pin 1) of the preceding buffer, IC2a.

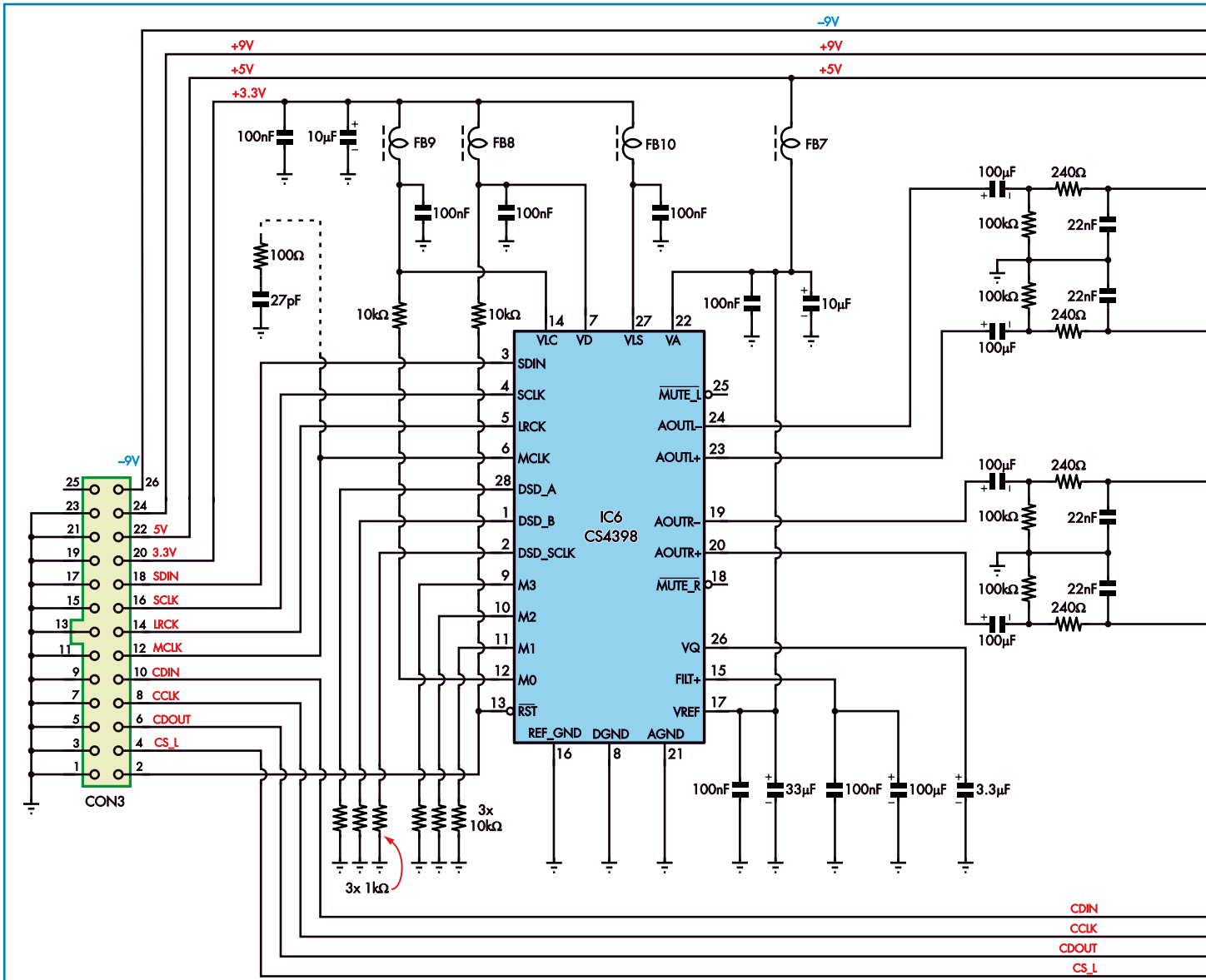
It may seem odd that the in-phase signal comes from the output of the inverter, but this is because the following filter stages are also inverting, so it will end up with the same phase as the inputs, while the other signal will be out of phase.

Both signals are then fed through identical buffer/filter arrangements, built around IC4a and IC4b. These filters are similar to what is recommended in the CS5361 data sheet (Figure 24), but not exactly the same. The data sheet says:

"The digital filter will reject signals within the stopband of the filter. However, there is no rejection for input signals which are (n×6.144 MHz) the digital passband frequency, where n=0,1,2, … Refer to Figure 24 which shows the suggested filter that will attenuate any noise energy at 6.144 MHz, in addition to providing the optimum source impedance for the modulators."

The main difference between our circuit and the recommended circuit is that ours is inverting. While inverting amplifiers introduce more noise than non-inverting amplifiers, inverting amplifiers can have lower distortion due to their near-zero common mode voltage. Also, the use of inverting amplifiers allows us to easily provide a slightly different DC bias to the two signals.

This is done one by connecting a low-value resistor (8.2Ω) between the non-inverting input pins (pins 3 & 5) of op amps IC4a/IC4b, which are in series with a divider across the supply rail (10kΩ/10kΩ).



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DSP CROSSOVER

DAC BOARD CIRCUIT

Fig.5: the DAC board does the opposite of the ADC board, converting the digital audio signals from the microcontroller back to balanced analog signals, then converting these to single-ended audio signals so they can be fed to stereo RCA output connector CON4.

The reason for DC biasing the two differential inputs differently is to overcome a potential problem with analog-to-digital converters, that when the signal is near the 'zero point', the binary values at the output tend to flip between all zeros and all ones. This can cause digital noise at the worst possible time – when there is near silence at the inputs.

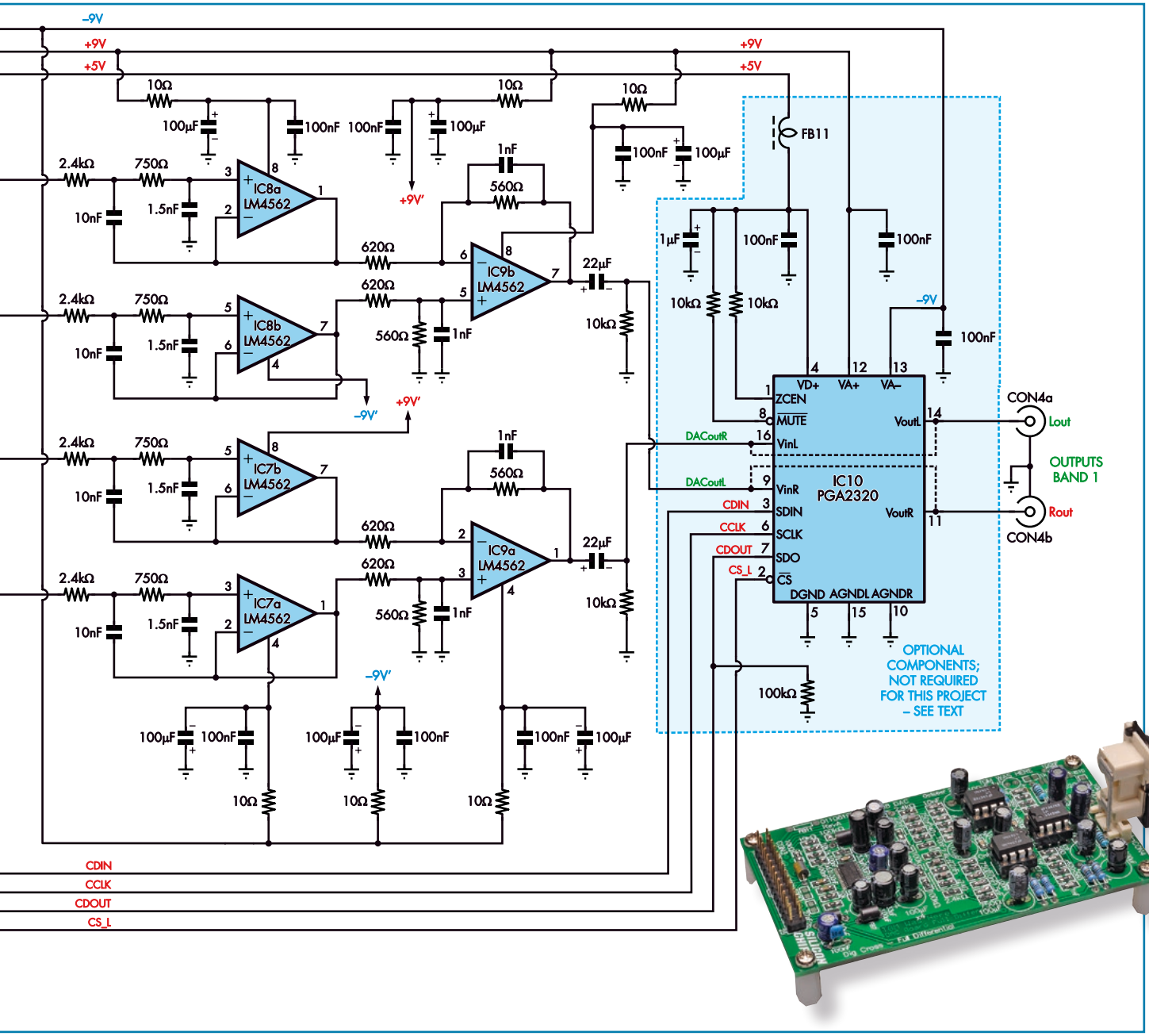
By adding a slight DC offset, the zero point is moved such that any small amount of noise will only cause a few bits to flip. That offset is removed by digital filtering inside the ADC chip. While modern delta-sigma ADCs do not suffer from this problem anywhere near as severely as early ADCs, this solution is cheap insurance to guarantee that the bit flipping problem does not affect us.

The bottom end of the divider which produces the half-supply bias rails is bypassed with 10µF and 100nF capacitors, to reject any noise and ripple that may be on this rail and prevent it from getting into the signal path. The ADC runs from its own regulated 5V rail which should be pretty 'quiet'. But this is a very high-performance ADC, so it isn't worth taking any risks in feeding noise into its inputs.

The 91Ω series resistors at the op amp outputs protect the ADC from excessive voltages. The op amps run from ±9V while the ADC runs from 5V, so the op amps outputs can swing beyond both of the ADC supply rails. But since the op amp feedback comes from after this resistor (ie, it's inside their feedback loops), the output impedance is still very low, and the frequency response is flat.

Schottky diodes D5, D6, D9 & D10 help to further protect the ADC inputs, by conducting if the op amps try to drive the ADC inputs below -0.3V or above +5.3V. This prevents any standard silicon devices (eg, transistors or diodes) inside IC1 from conducting due to an excessive input voltage, as usually this will only happen once the applied voltage is more than 0.6V beyond the supply rails.

The 91Ω resistors also combine with a 2.7nF capacitor across the differential inputs of IC1, to provide some further



differential filtering, to keep out any signals at 6.144MHz or above (the ADC's internal clock rate), which could affect the signal quality through aliasing.

Analog to digital conversion

The stereo differential signals are applied to input pins 16, 17, 20 & 21 of IC1. There are some extra components connected to this IC, which are required for its correct operation.

It has two internal reference voltages, which are fed to pins 22 (VQ or quiescent voltage) and 24 (FILT+) and these need to be externally bypassed to ground via capacitors. We have provided two capacitors to filter each of these rails, 10nF in both cases, plus 220µF for FILT+ and 1µF for VQ. The use of two different values provides a lower impedance across a broader range of frequencies.

IC1 has three different supply pins: VA (pin 19) for the analog 5V supply, VD (pin 6) for the digital 5V supply and VL (pin 8) for the 3.3V logic/interface supply. The supply arrangement is described below.

Pin 1 is IC1's reset input, and this is connected to the logic supply via a diode and resistor, and to ground via a capacitor. This forms a power-on reset circuit. Initially, the capacitor is discharged and so the reset input is low, resetting IC1. This capacitor then charges up via the 10kΩ resistor and releases reset after a few milliseconds. When power is switched off, the capacitor rapidly discharges via D13.

This reset pin is also connected to pin 2 of CON2, which is routed to the microcontroller, so it can reset IC1 after power-up if necessary.

Pin 2 selects either master mode (when high, ie, IC1 drives the digital audio clock lines) or slave mode (when low, ie, IC1 is clocked externally). This is connected directly to ground since the audio clock signals are supplied from the microcontroller via pins 12, 14 and 16 of CON2. These connect to pins 5, 3 and 4 of IC1 respectively, and in slave mode, these are the clock inputs.

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Pin 5 (MCLK) is the master (oversampling) clock, which is typically around 12.288MHz, ie, 48kHz x 256. This is used to clock the ADC modulator and other internal circuitry. Pin 3 is the left/right clock or sample clock, and this is usually at around 48kHz. When it is high, the serial data pin is normally carrying left audio channel data when it is low, right audio channel data.

Pin 4 is the sample clock and this clocks the serial data itself. It usually operates at the sampling rate times the number of channels, eg, 48kHz x 2 = 96kHz. The serial data comes from pin 9 of IC1 and goes to pin 18 of CON2, where it eventually feeds into the microcontroller.

Note that pin 5 (MCLK) of IC1 has a snubber network connected to ground. This is intended to prevent ringing and is a good idea when a high-frequency signal is fed through a long wire, however, at 12.288MHz it was found not to be necessary, and so those components can be safely left off.

ADC configuration

Pins 10-14 of IC1 are configuration inputs and their state determines how the ADC operates.

Pin 10 (MDIV) causes the master clock signal to be divided by two when high, allowing a higher frequency master clock to be used. Pin 11 enables or disables a digital high-pass filter, to remove any DC offset from the input signals. Pin 12 selects the digital audio output data format, either I^2S or left-justified.

Pins 13 & 14 select the sampling rate range, either single-speed mode (2-51kHz, M0 & M1 low), double-speed mode (50-102kHz, M0 high) or quad-speed mode (100-204kHz, M1 high).

Of these five pins, pin 12 (I2S/$\overline{LJ}$) is tied to VL via a 10kΩ resistor, permanently selecting I^2S format. The other four connect to jumpers JP1-JP4 and have 10kΩ pull-ups to VL. So they are high by default but can be pulled low by placing a shorting block on the jumper.

Typically, all four jumpers are fitted, so that master clock division is disabled, the high-pass filter is enabled and the sampling rate can be 48kHz.

But the use of jumpers means that you could change the software (eg, to use a higher sampling rate) and easily reconfigure the ADC board to suit.

Pin 15 of IC1 goes low if either input signal swings outside the range that the ADC can cope with. We have an LED (LED1) connected to this pin, with a 1kΩ current-limiting resistor to VL. So LED1 will light if the input signal level is too high for IC1 to cope with, resulting in digital clipping.

Power supply rails

The 5V analog supply comes from the output of an MC33375D low-dropout regulator, REG1, which is fed from the incoming +9V supply via a ferrite bead (FB3). This regulator was chosen for its very tight line and load output specifications (2mV and 5mV respectively), which means that the resulting analog 5V rail should be very stable indeed.

REG1 has 100nF and 220µF input bypass and output filter capacitors, but there are also four bypass capacitors right near IC1's VA input pin: 10nF, 100nF, 1µF and 10µF. Again, these different values were paralleled to provide a very low supply source impedance for IC1 across a wide range of frequencies, from a few hertz up to many megahertz.

The 5V digital supply, VD, is powered from the same 5V rail as VA but with a 5.1Ω resistor in between so that digital noise does not feed back into the analog supply. The VD rail has a separate 10nF bypass capacitors for high-frequency stability.

The 3.3V logic supply comes from pin 20 of interface header CON2, via another ferrite bead (FB6) and is bypassed with 10nF, 100nF and 1µF capacitors.

The ±9V supply rails for the op amps (also used to derive the 5V rails) are fed in via pins 24 & 26 of box header CON2, with series ferrite beads to stop RF signals from propagating in either direction. This is important since long unshielded ribbon cables can pick up all sorts of EMI.

Microcontroller interface

CON2 carries the power supply, control and digital audio signals. It's a 26-pin DIL header which connects to a ribbon cable. By tying all odd numbered pins to ground (except for pin 25), every second wire in the ribbon cable is grounded, minimising interference between adjacent signals on the even-numbered pins.

As previously mentioned, pins 20, 24 & 26 provide power to the ADC board while pins 12, 14, 16 & 18 carry the clock signals and digital audio data, and pin 2 is the reset line. Pins 22 & 25 are unused, leaving pins 4, 6, 8 & 10 which are reserved for an SPI control bus.

But IC1 does not have an SPI control interface, so those pins are not routed anywhere on this board.

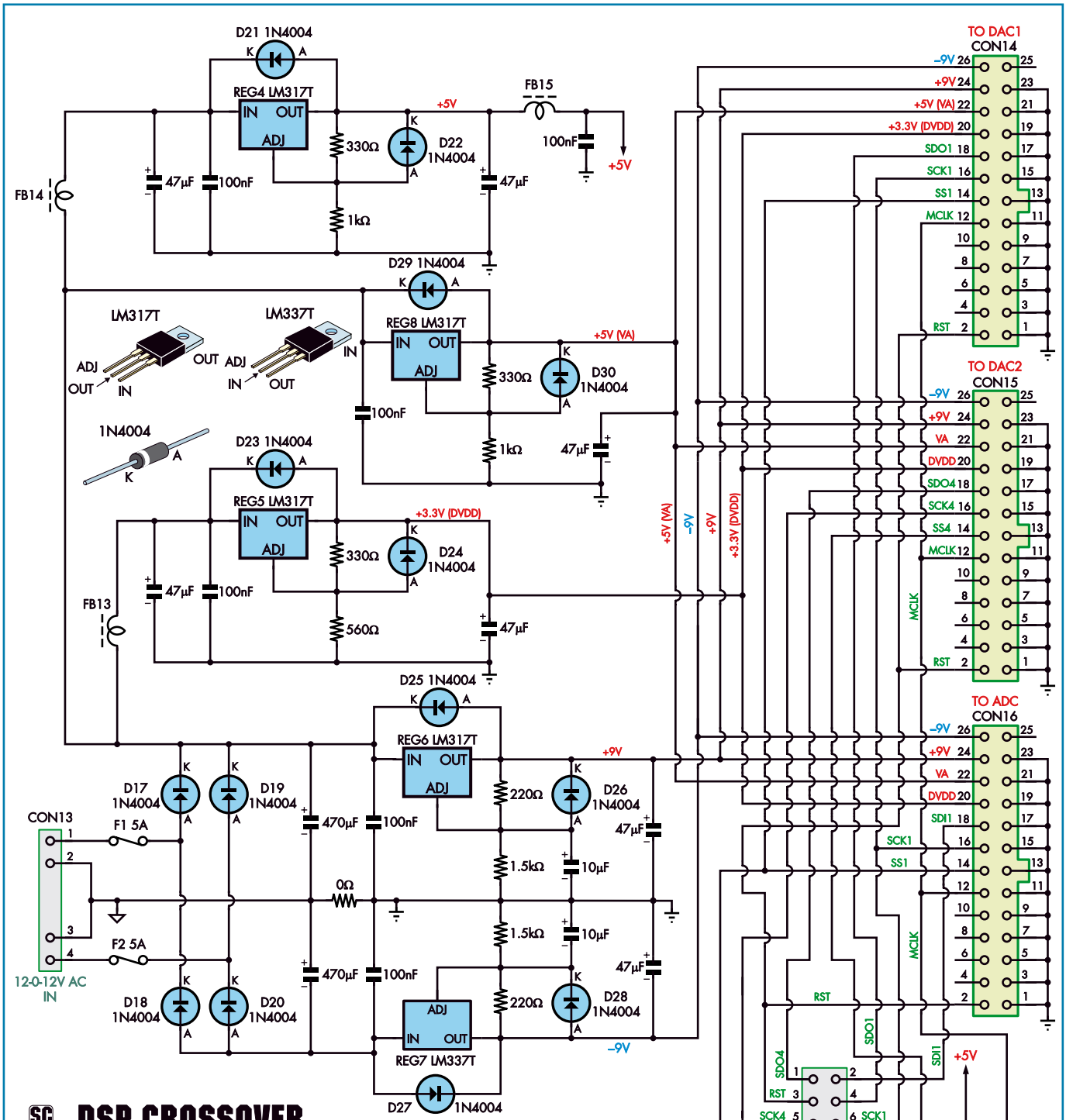
DAC circuitry

Now let's turn our attention to the DAC board circuit, shown in Fig.5. Essentially, its job is the opposite of the ADC circuit shown in Fig.4.

Rather than turning two analog audio signals into digital data, this circuit takes digital data and produces two low-distortion analog audio signals.

DIL header CON3 is another 26-pin header and it uses essentially the same pinout as CON2 in Fig.4. As before, odd numbered pins other than pin 25 are tied to ground. Pins 20, 22, 24 & 26 supply power to the DAC module while pin 2 is reset, pins 4, 6, 8 & 10 are the SPI control bus and pins 12, 14, 16 & 18 carry the digital audio clocks and data.

As with the ADC board, there is a snubber on the MCLK line (at pin 6 of IC6), but this is not strictly necessary and can be omitted. Also, there is no automatic reset network



DSP CROSSOVER

POWER SUPPLY/SIGNAL ROUTING

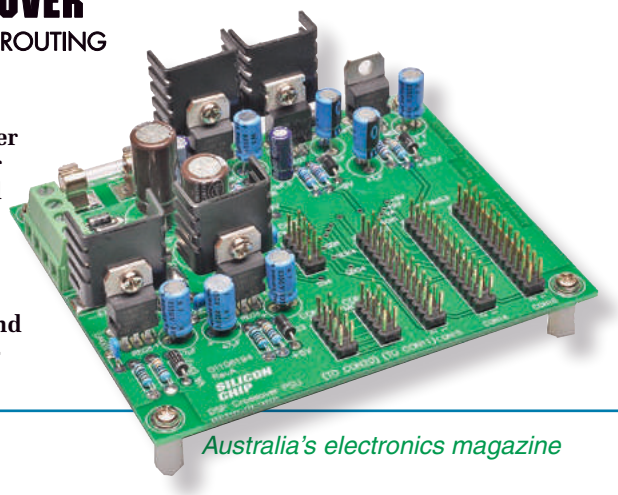


Fig.6: the power supply board has a bridge rectifier (D17-D20) plus five linear regulators and powers all the rest of the circuitry from the 9V AC or 9-0-9V AC fed to CON13. It also routes all the signals between the ADC, DAC and PIC32 boards via CON14-CON19.

on pin 13 of IC6; instead it is merely pulled up to VD (3.3V) via a 10kΩ resistor and connected to pin 2 of CON3. So the micro must forcibly pull this pin low to reset IC6.

The digital audio data is fed straight to pins 3-6 of IC6. While this chip does have an SPI control interface on pins 9-12, it can also be operated without it. This 'hardware mode' is selected by keeping pin 9 (control data input) at a DC level for a certain period after reset.

In this case, pins 9-12 become control inputs. That is how it is being used here. Pin 12 (M0) is pulled high via a 10kΩ resistor to the VLC (logic supply) pin while the other three pins (M1-M3) are connected to ground via 10kΩ resistors. This selects single-speed (32-50kHz sampling rate) I^2S mode without digital de-emphasis.

Like the ADC, DAC chip IC6 needs external filter capacitors for two internal reference rails, and these are connected between pin 15 (FILT+) and ground, and pin 17 (VREF) and ground.

Analog audio appears at pins 19, 20, 23 & 24. As with the ADC, these are differential signals. They are AC-coupled using 100µF capacitors with 100kΩ biasing resistors to remove the DC component of the output signals. They are then fed to third-order (-18dB/octave) active low-pass filters built around low-distortion LM4562 dual op amps IC7 and IC8.

These filters are different from the recommended filter in the CS4398 data sheet, but they have the same purpose: to remove the high-frequency delta-sigma switching artefacts from the analog audio signals.

These filters have a -3dB point of 30kHz and are down to -90dB by 1MHz. But the response is down by only around 0.3dB at 20kHz, with a very flat passband, so has minimal effect on audio frequency signals.

The differential output from the two pairs of identical filters is fed into a differential amplifier which provides further filtering, based around either IC9a or IC9b. This also converts them to single-ended signals.

These stages provide some gain, to boost the ~1V RMS from the DAC up to around 2.3V RMS, a similar level to that produced from many other audio sources like CD/DVD/Blu-ray players

The signals are then AC-coupled by 22µF capacitors and DC-biased to ground using 10kΩ resistors, to remove any remaining DC bias on the signals. They are then fed to the inputs of IC10, a PGA2320 volume control chip.

There are two things to note about this chip. One is that we're feeding the left channel signal to its right channel input and the right channel signal to its left channel input. But that doesn't matter since its channels are independent.

The other is that the CS4398 already has a built-in digital volume control. IC10 is included on the board because it adds little noise to the signal and since the signal swing is higher at the outputs, we thought that this would introduce less distortion. And that is true, but the effect is quite small, so we didn't even bother wiring up the control signals from IC10 to the microcontroller.

So you can leave it off the board and instead, solder 0Ω resistors from its pin 9 pad to pin 11, and another from pin 16 to pin 14, so that the signals from IC9 go straight to the output RCA connectors, CON4.

While it may seem odd that there's a footprint for IC10 when it isn't connected to the microcontroller, it could be useful if the board was used in a different project, and there was space on the board, so we've left the option open.

Power supplies

As with the ADC board, the op amps run off the ±9V supplies fed in from the power supply board via CON3. However, rather than passing through ferrite beads, on this board each op amp has a 10Ω/100µF RC low-pass filter for each supply rail, as well as 100nF bypass capacitors for each op amp supply pin.

Another difference from the ADC board is while that board derived a local 5V supply from +9V using an onboard regulator, on this board, DAC IC6 and (if fitted) volume control IC10 run from a 5V supply that's fed from the power supply board, via pin 22 of CON3.

The two chips have separate ferrite beads on this supply line for isolation, plus small and large bypass capacitors.

DAC IC6 also requires three 3.3V supply rails – one for I/O (VLC, pin 14), one for its digital circuitry (VD, pin 7) and one for its internal PLL (VLS, pin 27).

These are all powered from the same 3.3V supply rail via pin 20 of CON3, but again they have separate ferrite beads for EMI suppression and isolation, plus individual 100nF bypass capacitors.

There are also 100nF and 10µF capacitors on the incoming 3.3V supply rail.

Volume control

As mentioned earlier, volume control chip IC10 is not required, but if it is fitted, it is powered from the ±9V rails (at the VA+ and VA- pins) and also from the 5V rail via ferrite bead FB11. The ZCEN input (pin 1) is pulled up to +5V with a 10kΩ resistor, while $\overline{\text{Mute}}$ (pin 8) is similarly pulled up by a 10kΩ resistor.

Pin 1 is the Zero Crossing Enable control and when pulled

The completed project (June and July issues) will include a 128 x 64 graphical LCD which lets you set up the unit and see how it is configured. It is controlled using a rotary encoder and two pushbuttons to drive the menu-based interface.

high, it will wait for the audio signal to cross through 0V before making any volume changes. This avoids clicks which would otherwise be caused by a sudden signal level step change when the volume is adjusted.

Unsurprisingly, pulling pin 8 low mutes the output, and this function is not used, hence the pull-up resistor. Mute can instead be controlled using the SPI serial control interface.

Power supply and signal routing board

Let's turn now to the power supply and signal routing circuit, shown in Fig.6. The cable from CON1 on the ADC board connects to CON16, while two separate but identical DAC boards are connected to CON14 and CON15.

10-way headers CON17 and CON18 connect to the microcontroller board. The signals to and from the ADC and DAC boards are routed to the microcontroller pins via these headers. At the same time, five power rails are distributed to all those boards as required.

Except for the master clock, all the signals from CON18 are connected through to CON19, which the front panel control board plugs into. This routes the control board signals back to the microcontroller.

Some things to note about the signals passing between the micro and ADC/DAC boards: CON14 (DAC1) and CON16 (ADC) share the same digital audio bus, while CON15 has a separate bus. One DAC and one ADC module can share the same bus since there is one pair of data in/out lines and they only use one each (into the DAC, out from the ADC).

The same master clock signal is distributed to all three connectors, and the reset line is also shared between all three, so the three chips will be reset simultaneously if this line is pulled low.

None of the SPI control buses are wired up to anything, as this is not required as long as you leave the volume control chips off the DAC boards.

The ADC and DAC boards are fed with +9V, -9V, +5V (VA, not used by the ADC board) and +3.3V (to power the digital interfaces of the ADC and DACs). A separate 5V rail passes through ferrite bead FB15 and is then fed to the microcontroller board, to power the micro. Using a separate rail avoids the possibility of the micro board 'polluting' the 5V rail used by the DAC boards.

All the digital audio signals connect to the micro via CON17 (along with its 5V supply), except for the master clock, which is on pin 8 of CON18. The other pins on CON18 are wired to general purpose I/Os on the microcontroller.

The power supply section is pretty straightforward: a centre-tapped 18-24V AC (eg, 12 + 12V AC) transformer is wired to CON13 and then connects to diode bridge rectifier D17-D20 via fuses F1 and F2.

The DC outputs of this bridge are filtered by a pair of 470µF capacitors and then regulated by adjustable regulators REG6 and REG7 to produce the +9V and -9V rails respectively.

LM317/337 adjustable regulators are used because of their excellent ripple rejection capability, especially with 10µF capacitors from their ADJ terminals to ground. The 220Ω and 1.5kΩ resistors set their nominal output voltages to (1.5kΩ/220Ω+1) x 1.2V = 9.38V. The extra diodes protect the regulators by preventing current from flowing backwards through them at switch-off.

These regulators are fitted with small flag heatsinks to keep their temperatures reasonable.

The positive output of the bridge rectifier is also fed through ferrite beads FB13 and FB14 through to two extra 47µF capacitors which power regulators REG4 and REG5 respectively, to produce the +5V and +3.3V rails. Different feedback resistor values are used to change the LM317 output voltages.

The extra ripple-rejection capacitors are not used here since these supplies do not need to be as 'quiet'.

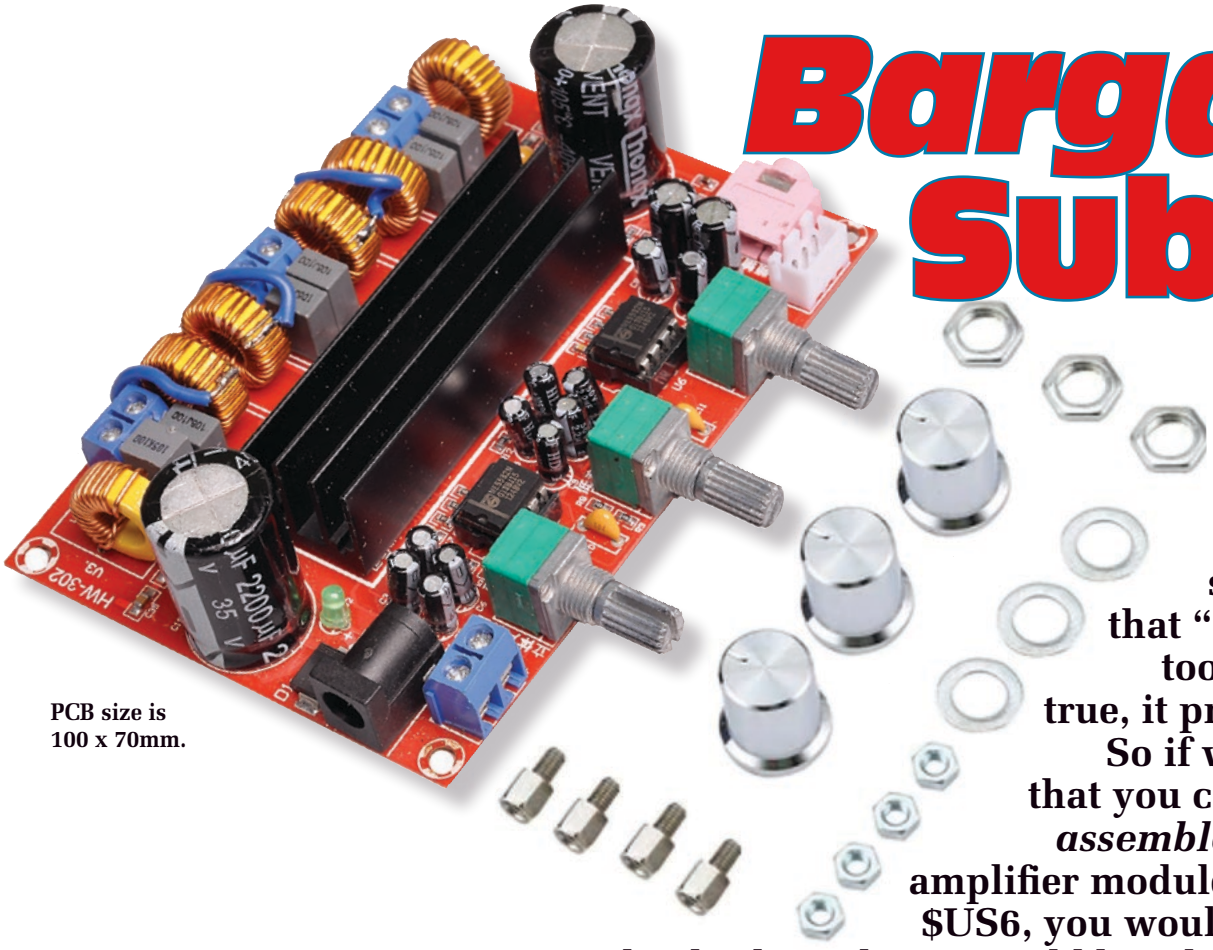
Another LM317, REG8, is fed from the main 470µF positive filter capacitor and is also set up for a 5V output. This provides the 5V "VA" rail for both DAC boards.

Coming up . . .

This is a monster project, so we can't fit all the details into a single article.

Over the next two issues, we plan to have details on the microcontroller and front panel circuits, along with the parts list plus construction and operation of the of the SC

Bargain Subwo



PCB size is 100 x 70mm.

The old saying says that "if it sounds too good to be true, it probably is". So if we told you that you could get an *assembled* 3 x 50W amplifier module for *under* $US6, you would probably be thinking that it would be a load of junk. But in this case, that isn't the case! This one works almost (!) as well as advertised – and most of its shortcomings can easily be addressed.

The Class-D 3 x 50W amplifier module (stereo plus subwoofer) shown above can be purchased (at time of going to press) for about $US6 from eBay or AliExpress.

For a bit more money, you can get the 5x50W amplifier module with built-in Bluetooth support shown opposite.

Both run from 5-27V DC, provide decent performance and appear to be very good value for money.

The XD172700 module

The module above uses the latest power IC from Texas Instruments, the TPA3116D2 IC (2017 revision G), who describe it as a "15W, 30W, 50W Filter-Free Class-D Stereo Amplifier Family With AM Avoidance".

The chip measures just 11mm x 6.2mm. Two are used on the first board: one is used in stereo mode for the left and right channels and the other in mono (bridged) mode for driving a subwoofer.

These amplifier chips are fed audio by two NE5532 ICs used as preamplifiers and to provide the subwoofer low-pass filter.

You don't have to worry about soldering the SMD TPA3116D2 chips because this has all been done for you! Our suggested modifications require a little bit of soldering.

We paid sixteen dollars (Australian) including postage – and are feeling miffed at that, having since found them much cheaper! The board comes with everything, even the kitchen sink, err, heatsink, which is shared by both amplifier ICs.

It even came with a set of standoffs, nuts and bolts for mounting it in a chassis, plus a nice set of shiny knobs for the pots! All you need to do then is wire up the power supply, audio input and speaker output terminals.

The board has two audio input options: you can use either the 3.5mm stereo jack socket or a three-pin JST header. And there are two options for power supply; either a PCB screw terminal or a 5.5mm DC barrel socket for a plugpack or inline power supply.

The board requires a simple DC supply, and this simplifies things significantly because you can use just about any supply that produces 5-24V DC such as an old laptop supply or any other high current source, including a car battery, electric drill battery etc. You could even use a 5V USB charger. But to get the full output power, you need around 24V at 6-7A.

Note that to get the full power output you will also need 4Ω speakers. Higher impedance speakers cannot be driven to quite as high power levels. For example, if you use 8Ω speakers, with the appropriate power supply, you will get around 30W maximum from the left and right channels.

The amplifier ICs have a high power supply rejection ratio (PSRR), so you don't need a super smooth DC supply.

Class-D Stereo + oofer Amplifier Modules

By Allan Linton-Smith

It will reject 70dB of ripple, meaning you can have up to 200mV peak-to-peak ripple before you're likely to notice any buzz or hum creeping into the audio outputs.

For testing, we used a 24V 7A DC plugpack which cost $33 including postage. 24V x 7A = 168W so with a 90% claimed peak amplifier efficiency, we should get a total theoretical output of around 150W RMS, ie, around 2 x 38W into 4Ω for the left and right channels and about 75W into a 2Ω subwoofer.

The efficiency of the device varies significantly with supply voltage and output power (see Fig.1). It is typically 40-70% at low power levels, ie, below 5W. If you only require power levels up to 10W into 4Ω speakers you are better off with a 6-12V DC supply because this will give you 70-90% efficiency and it won't cause any overheating problems (see Fig.1).

So your best approach is to decide what power output you need and then choose your power supply to deliver this with the highest efficiency. Otherwise, the device may overheat and automatically shut down during use.

Power output figures

The measured power for this module is good but not quite up to the claim of 2 x 50W + 100W.

During testing, we did manage to get 2 x 50W into 4Ω and 2 x 30W into 8Ω as expected. But we were not able to get the full 100W into 2Ω from the subwoofer output because the device protection circuit sent the output into high impedance and it cut out. We were only able to get about 50W into the sub.

This is no doubt due to poor design of the subwoofer section; we suspect that the IC has not been correctly configured for mono operation. It may be possible to fix this by changing some of the passive components connected to the subwoofer amplifier IC, but we haven't tried that.

So basically, you can expect to get about the same amount of power from the subwoofer channel as you can from the left and right channels, taking into account the possibility that your sub may have a different impedance from the other speakers.

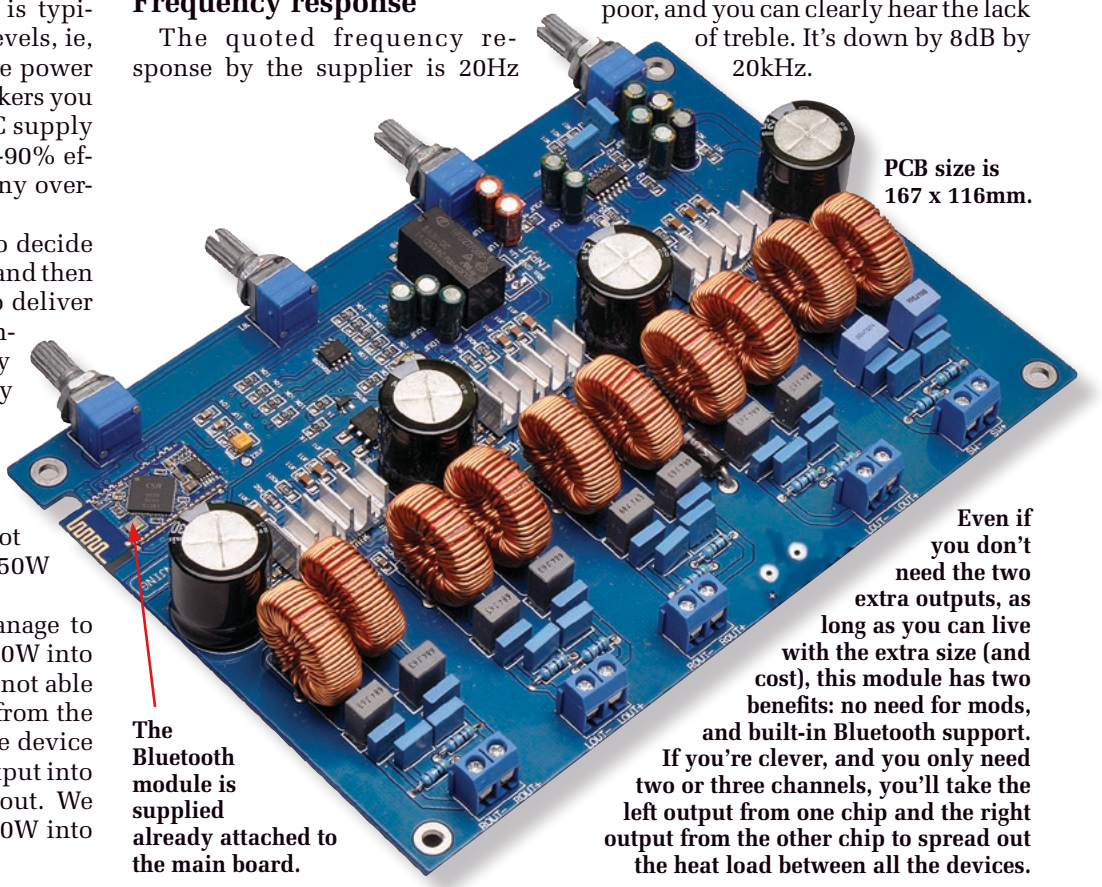
Frequency response

The quoted frequency response by the supplier is 20Hz to 20kHz with no plus/minus decibel figure, which is quite common to see but also a pretty-much useless statement. So we decided to measure the frequency response accurately.

First, we did a listening test which exposed a lack of treble with cymbals, triangles and slightly muffled brass. The measured response, as shown in Fig.2, confirms our subjective impression.

There is a significant drop-off in the output above 1kHz. We did this test at 1W and 5W output levels, using a 12V DC supply for convenience.

So the out-of-the-box response is poor, and you can clearly hear the lack of treble. It's down by 8dB by 20kHz.



PCB size is 167 x 116mm.

The Bluetooth module is supplied already attached to the main board.

Even if you don't need the two extra outputs, as long as you can live with the extra size (and cost), this module has two benefits: no need for mods, and built-in Bluetooth support. If you're clever, and you only need two or three channels, you'll take the left output from one chip and the right output from the other chip to spread out the heat load between all the devices.

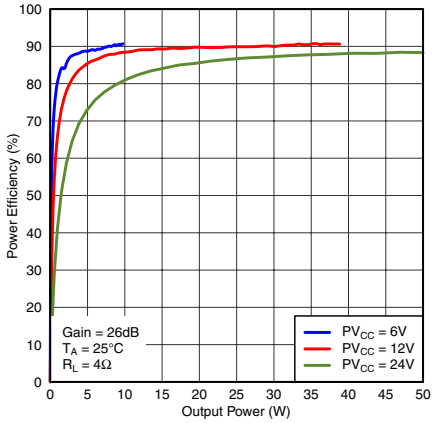


Fig.1: sample efficiency curves from the Texas Instruments TPA3116D2 data sheet. Efficiency is higher with lower supply voltage but of course, maximum power is also lower in those cases. Efficiency also increases with output power; in other words, device dissipation does not increase much as the output power rises.

A glance at the Texas Instruments data sheet (www.ti.com/lit/ds/symlink/tpa3116d2.pdf) indicates that when properly implemented, the IC's frequency response should be almost ruler flat to about 40kHz.

The data sheet also recommends that the LC filter after the output stage, if fitted, should have a 10µH inductor and 680nF capacitor on each output pin.

However, we measured the supplied LC filter at 55µH and 1µF, which would explain the drastic reduction in high-frequency response. We tried reducing the output inductor values to 10µH, which considerably flattened the frequency response.

As per the data sheet, high-current ferrite beads can be used in place of the inductors, if the capacitors are also changed to 1nF.

This will not be as effective at reducing radiated emissions, however, and doing this will require quite a bit of soldering which may damage the dual-layer PCB.

Changing the inductor values has another benefit besides flattening the frequency response; we found that they got hot during use because the wire used is too thin.

Audio inductors should be air-core types to avoid non-linearity in the core material.

We published instructions for winding 10µH inductors using 30.5 turns of 1mm diameter enamelled copper wire on standard bobbins available from Jaycar and Altronics.

This was in the August 2011 issue, on page 67 (siliconchip.com.au/Article/1129). It was intended for use in the Ultra-LD Mk.3 amplifier module but is certainly applicable to this one, too.

You then just need to remove the existing inductors and solder the improved ones into place. Keep them as close to the PCB as possible and mount them all with the same orientation to reduce problematic magnetic field interactions.

While you should ideally replace the 1µF capacitors with 680nF capacitors as per the data sheet, in practice, it doesn't make that much difference.

You can see the revised frequency respone (after changing the inductor values) as the blue trace in Fig.2

With the 10µH inductors and 1µF

XD172700 Class-D amplifier features and specifications

- 3 x 50W RMS into 4Ω (21V DC supply)
- 3 x 30W RMS into 8Ω (24V DC supply)
- Supply voltage: 4.5-27V DC
- THD+N: typically around 0.05% at 1kHz, 1W
- Frequency response: 20Hz-20kHz, +3,-0dB (after modifications)
- Efficiency: up to 90% (only needs a small heatsink)
- Switching frequency: 400kHz ±3kHz
- Self protection circuits: over-voltage, under-voltage, over-temperature, DC offset, over-current and short-circuit protection.
- Input connectors: 3.5mm stereo jack socket or 3-pin JST header
- Output connectors: 3 x 2-way terminal blocks
- Power connectors: 2-way terminal block and DC barrel socket
- Module size: 100 x 70 x 30mm

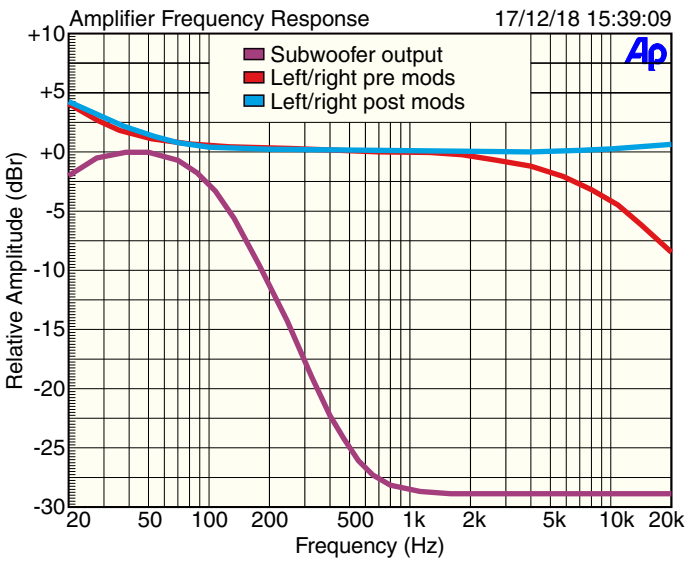


Fig.2: frequency response of the 2+1 channel amplifier module before and after we modified it. The mauve curve shows the subwoofer output, which purposefully rolls off at around 100Hz, the left/right response as supplied is in red, and post-mods is in blue. It's now much flatter above 1kHz, and it sounds a lot less muffled!

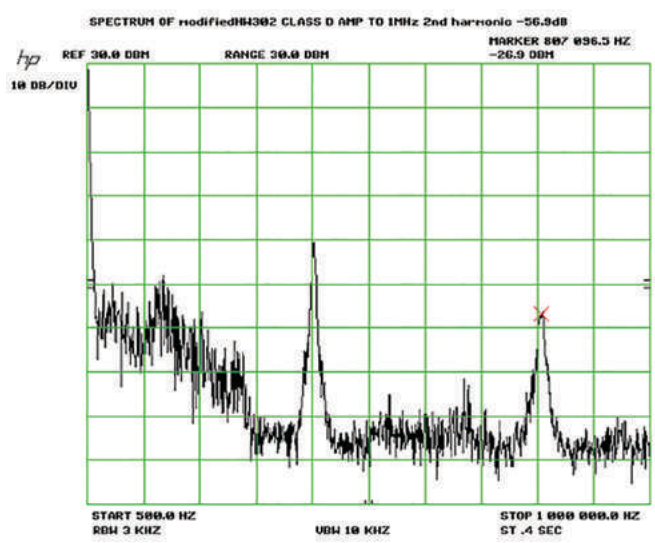


Fig.3: spectrum analysis of the output waveform shows that the main peak at 403kHz, representing what's left of the switching waveform after filtering, is 40dB below the audio signal while its first harmonic at 806kHz (in the AM broadcast band) is at -57dB, so the amplifier should not cause too much AM interference. Still, we'd keep the speaker leads as short as possible!

Yuanjing Class-D amplifier features and specifications

- Inputs: 3 separate channels (left, right, subwoofer)
- Outputs: 5 x 50W RMS into 4Ω (21V DC supply) or 5 x 30W RMS into 8Ω (24V DC supply)
- Supply voltage: 4.5-27V DC
- THD+N: typically around 0.05% at 1kHz, 1W
- Frequency response: 20Hz-20kHz, ±1dB
- Efficiency: up to 90% (comes with small heatsinks fitted)
- Switching frequency: 400kHz ±3kHz
- Self protection circuits: over-voltage, under-voltage, over-temperature, DC offset, over-current and short-circuit protection.
- Input connectors: 3-way pin header or Bluetooth wireless
- Output connectors: 5 x 2-way terminal blocks
- Power connector: solder pads
- Module size: 165 x 115 x 25mm

capacitors, it shows a slight lift at 20kHz, continuing to rise to 30kHz, then dropping sharply to -60dB at 1MHz.

Naturally, after doing that, the unit sounded much better, with an excellent high-frequency response; very different from our first listening test!

The subwoofer response is also shown in Fig.2. It has a peak at 28Hz and is -20dB at 250Hz, which is close to ideal.

The subwoofer amplifier can put out significant power and the IC is supposed to handle 2Ω speakers, but we found that 4Ω is the minimum for this particular module. You won't find many 2Ω drivers (outside of cars), anyway.

By the way, you may notice that after this modification, the module has a slight (2dB) rise at the low-frequency end, close to 20Hz.

This is probably due to crosstalk with the subwoofer section and the design of the PCB, but it should not be a problem because most loudspeakers will not respond to such low frequencies.

A small amount of low-end boost will generally improve the response of most loudspeakers anyway.

AM radio frequency avoidance

The TPA3116D2 has advanced oscillator/PLL circuitry which employs multiple switching frequency options to avoid AM interference.

These options cover 15 different frequencies, ranging from 376kHz to 1278kHz, so it can be set to avoid the AM band in most countries.

Our module was pre-set at 400kHz (403.5kHz measured) so that only the first harmonic will fall into our local AM band.

We also checked the output with a spectrum analyser and found that the first harmonic (807kHz) was 57dB lower than the audio output signal level, so there should be very little interference with AM radio receivers (see Fig.3).

If you are going to use the module in other places where 400kHz radiation could be a problem, you could modify the unit according to the data sheet, but that would be quite tricky.

So we suggest that you instead try to keep the speaker leads short – less than 1m if possible – so they make for poor transmitting aerials.

The spectrum from 500Hz to 40MHz is otherwise very clean.

Distortion and noise (THD+N)

The unit is quoted as having a THD+N figure of 0.1% at 1kHz with a 25W output. We decided to verify this with some measurements.

The maximum power into an 8Ω load is 40W RMS and the THD+N reading was 1% when clipping started to be noticeable at this level. The high THD+N at very low power levels is merely noise. As expected, the module will deliver 50W into 4Ω loads.

Fig.5 shows a plot of THD+N vs frequency for the module. These figures are the best that we were able to achieve after changing the output inductors. The distortion above 10kHz may be higher than indicated because we used a 20kHz "brick wall" filter

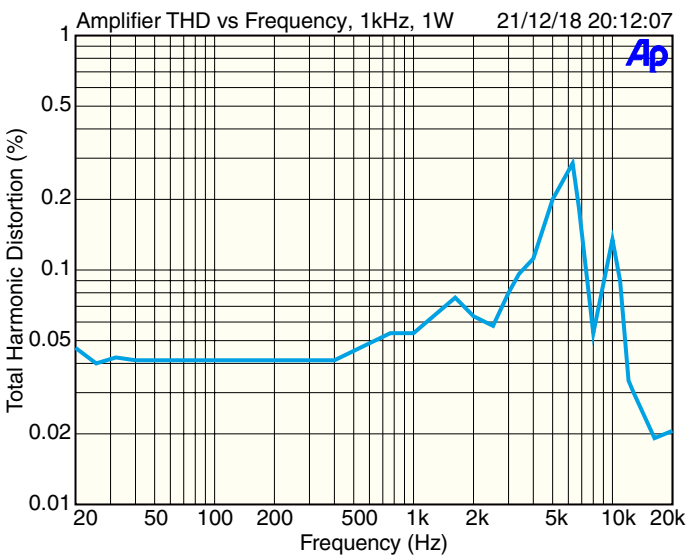


Fig.4: the measured distortion performance of the left/right channels on our sample module (after fixing the output filters), into an 8Ω resistive load. While not quite as good as the amplifier designs we publish, it's below 0.1% THD+N up to about 3.5kHz (with a 20kHz bandwidth) which is not too bad. It certainly sounds acceptable. We must use a 20kHz filter to remove the switching residuals, hence the drop-off in readings above about 6kHz, above which the main harmonics are filtered out.

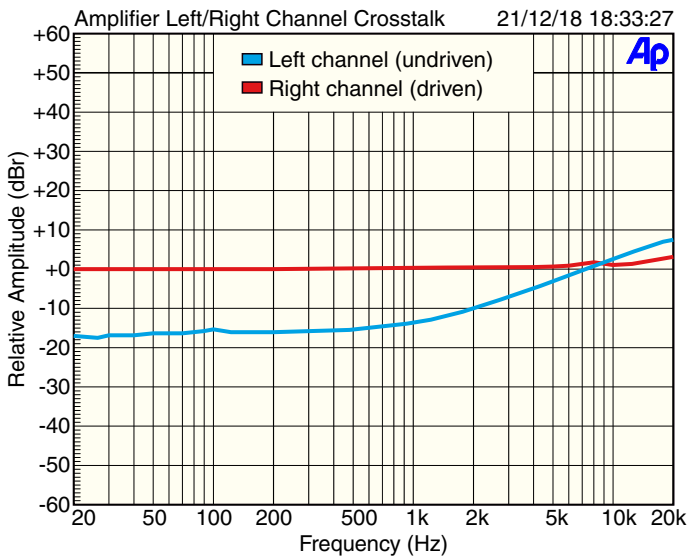


Fig.5: crosstalk figures for this amplifier are not particularly great, with less than 20dB separation between channels. This is probably due to the close proximity of the output filter inductors for each channel. This generally isn't a problem when playing regular music recordings, but if it bothers you, you have the option of using two separate modules, one for each stereo channel.

Fault Reporting

FAULT	TRIGGERING CONDITION (typical value)	FAULTZ	ACTION	LATCHED/SELF-CLEARING
Over Current	Output short or short to PVCC or GND	Low	Output high impedance	Latched
Over Temperature	T_j >150°C	Low	Output high impedance	Latched
Too High DC Offset	DC output voltage	Low	Output high impedance	Latched
Under Voltage on PVCC	PVCC < 4.5V	–	Output high impedance	Self-clearing
Over Voltage on PVCC	PVCC > 27V	–	Output high impedance	Self-clearing

Fig.6: the self-protection features of the TPA3116D2 IC.

to eliminate subharmonics from the 400kHz switching frequency, which otherwise would have affected the measurements.

The 80kHz bandwidth measurements we usually take with linear amplifiers cannot be made with Class-D amplifiers. Therefore, we took some intermodulation distortion (IMD) measurements to clarify the level of distortion at higher frequencies.

The IMD measurements were taken by injecting the SMPTE-standard frequencies of 500Hz & 2kHz (2:1) and the resultant spectrum shows acceptably low noise up to 24kHz. The average level is 0.11% which verifies the THD+N measurements; this is not bad for a Class-D amplifier.

Crosstalk

We checked out the crosstalk of the amplifier module (Fig.5) and the results were as not as good as specified, probably because of the design of the PCB and the interaction of the output inductors, which cause feedback into the opposite stereo channel.

There is not a lot you can do about this; it may be possible to re-locate the inductors or substitute ferrite beads, but if you want really good crosstalk performance, given its low cost, you could simply use a separate module for the left and right channels.

While we were working on this article, similar modules have appeared on eBay for around $5. So it's hardly worth arguing about!

Protection features

The TPA3116D2 is a well-protected device and has self-protection for over-voltage and under-voltage conditions as well as an output DC fault, short-circuit, overload and over-temperature conditions. When an over-current, short-circuit, over-temperature or DC offset fault is detected, the module switches itself off and you need to cycle power to restore its function.

No point changing the op amps

As mentioned earlier, the unit we obtained came with two NE5532 op amps in sockets. Most dual op amps in DIP-8 packages have the same pinout, so it's easy to swap them – but there isn't much point!

Firstly, while the NE5532 is an old design, it has stood the test of time and even by today's standards still has outstanding performance.

And secondly, the distortion and noise in this amplifier is dominated by the amplifier ICs themselves and not the op amp-based preamplifiers.

We tried replacing the NE5532 with newer OPA1642s (soldered to SOIC-

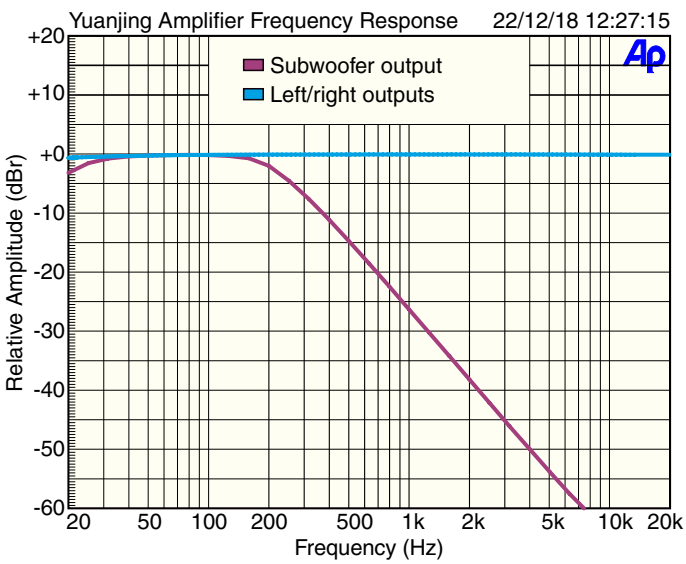


Fig.7: the frequency response of the Yuanjing-brand 4.1 channel amp is fine out-of-the-box, unlike the other one we tried. Note how its subwoofer low-pass filter is far less aggressive than the other board's, with significant amounts of low bass making it through, up to a few hundred hertz.

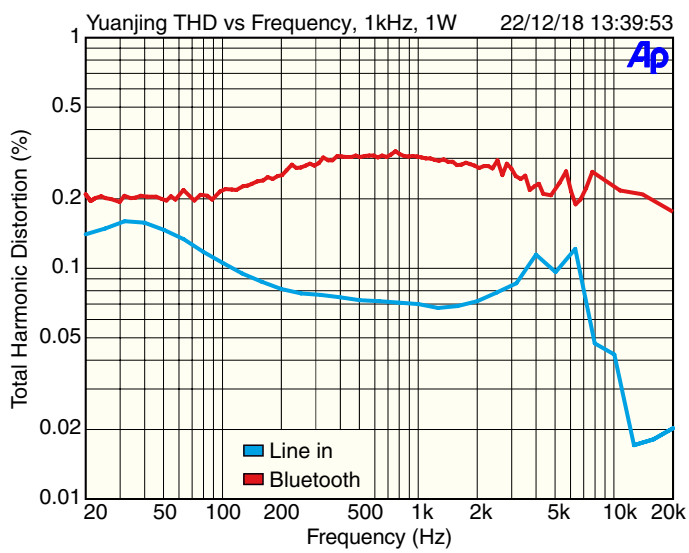


Fig.8: distortion performance is similar to the cheaper one; slightly worse at lower frequencies (probably due to the use of less-linear coupling capacitors), and slightly better at higher frequencies. Its performance is significantly better when using the line input pin header compared to Bluetooth, likely to due to digital artefacts and noise in the output of the Bluetooth module.

to-DIP adaptors) but the improvement in performance was so minor as to be insignificant. If you must change the op amps, don't forget to fit them in the right orientation!

Getting one

There are many similar modules available with a different size, layout, components, connectors and so on. You may want to look for one that's visually identical to ours, since it is at least a known quantity. There are many possible sources but here is one to get you started: **www.aliexpress.com/item//32810347968.html**

The Yuanjing module

Since we noticed so many other similar modules were available, we decided to try a second one, specifically, one with built-in Bluetooth support.

The one we've chosen has no obvious model number but since it has "Yuanjing" written in copper tracks in the corner near the Bluetooth module, and this is presumably the manufacturer, that's how we're referring to it.

You can find this module for sale at prices from about $US28 to $US50 on eBay and AliExpress, although the latter has a better selection. Search for "tpa3116 4.1" and look for a blue PCB matching the one shown in this article.

This one appears to be the best deal at the time of writing: **www.aliexpress.com/item//32799510099.html**

We're guessing that this module is designed for motor vehicles given that it has two pairs of essentially identical left/right outputs – these could be used to drive front and rear car speakers. The four pots along the front control overall volume, subwoofer volume and front and rear volume independently.

Even if you don't need the extra channels, there are two big advantages to this module. One, we didn't need to make any modifications to get good performance out of it; it appears to have the correct output filter components from the factory. And two, the built-in Bluetooth audio receiver is very handy for wirelessly playing audio from a mobile phone or tablet.

It works seamlessly. When a Bluetooth device is connected, it switches a relay to divert the Bluetooth audio to the amplifier chips. With no Bluetooth connected, audio comes in via a three-way pin header. The subwoofer signal is generated by mixing the left and right channel signals and then feeding it through a low-pass filter.

Like the XD172700, the subwoofer output on this module does not appear capable of the claimed 100W. We think that in both cases, they simply have not wired up the IC correctly for BTL operation. It's merely using one of the two available channels and so is only capable of driven 4-8Ω loads to the same power levels as the left and right channels.

But still, overall, the performance isn't bad, especially considering the price and the convenience of running off a single, relatively low voltage DC supply rail!

Figs.7-9 show how the performance of the Yuanjing module compares. It's certainly usable as-is and is comparable to, or better than the XD172700 module in most areas.

Just one point to note: while this module comes with the appropriate pot nuts and washers (as seen in the photo) it doesn't include the stand-offs nor the cute knobs which the other one has. Oh well – can't win 'em all!

Conclusion

These fully built and ready-to-go modules are very flexible and would have many useful applications such as in cars, TV soundbars, computer sound systems, amplifiers for smartphones etc. They should be very reliable due to their comprehensive protection against short-circuits and importantly, against overheating.

The fact that they only require a single DC supply and can run from 5V to nearly 30V makes them even more flexible. You can even get a few watts of audio output using a small USB charger!

The distortion, frequency response and crosstalk could all be improved but for the price, we didn't expect super hifi performance.

These modules can easily be mounted inside a cheap Jiffy box or metal amplifier chassis. It's so straightforward, we aren't even bothering to give any instructions. Just mount them in the chassis, wire them up and away you go. SC

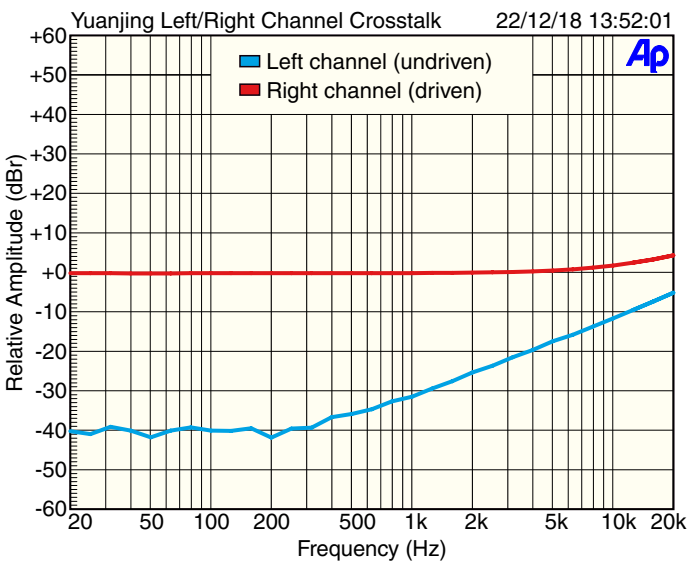
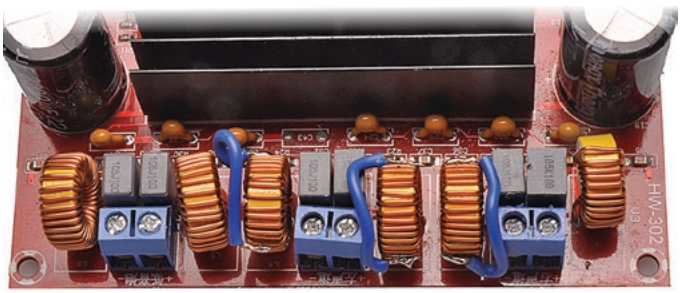


Fig.9: crosstalk for the Yuanjing amplifier isn't exactly great but it's significantly better than the cheaper one. You're not likely to notice this coupling when listening to ordinary program material with stereo speakers.



As noted in the article, the inductors on the 172700 unit had way too high a value to give a good frequency response. Not wanting to spend any money on new inductors (they would cost more than we paid for the whole module!) we tried partially unwinding some of them. That worked, but it was a lot of work. So for the remainder, we shorted out 15 turns by soldering thin wires in place (after scraping off the enamel insulation from the wire), as seen here. This dropped their inductance down into roughly the right value.

433MHz Wireless Data Range Extender

by John Clarke

There are many "remote control" devices which rely on a 433MHz data link. You may have one and not even realise it – an alarm remote, a garage door/gate controller or even an outdoor weather station are just some examples. But is yours 100% reliable? Is the range a bit less than you'd like? Perhaps the remote unit is too far away from the receiver – or are there hills, trees or other obstacles in the way? Here's the answer: a small, solar-powered repeater that you place between the transmitter and receiver with clear line-of-sight to both. You'll end up with the reliability – and the extra range – you need.

There are quite a few devices which transmit periodic bursts of data on the 433MHz UHF "LIPD" band, including a number of our designs, such our Driveway Monitor (July & August 2015; siliconchip.com.au/Series/288).

This includes some commercial devices too, such as remote weather stations. Unfortunately, it isn't always possible to get reliable reception.

Sometimes this is because there are hills, trees, buildings etc between the transmitter and receiver locations.

Other times, it's because of limited antenna sizes or the 25mW legal limit placed on unlicensed devices operating in this band (many 433MHz transmitters are far weaker than this).

Even the weather can have an impact: a shrub or tree that has little to no effect in dry weather can play havoc with UHF signals in the wet.

While 433MHz signals aren't attenuated as much as higher frequencies (eg, 2.4GHz, which is also used for data), if you're suffering from marginal signal anyway, it could be enough to stop data getting through.

This repeater can be placed in a location where it can clearly and reliably receive signals from the transmitter, and which is also a better location for reception by the receiving unit (ie, it can be placed somewhere in between the two devices).

It stores the received data and then, after a short delay, re-transmits the same signal in the same frequency band.

So this design is suitable for extending the wireless range by up to two times, where line-of-sight transmission is possible.

But it's also extremely effective at improving the signal integrity where the two units have obstructions between them, in-

Features

* Extends the range of 433MHz transmitters
* Overcomes 'line-of-sight' limitations caused by trees, obstacles etc
* Receives 433MHz signal and re-transmits at 433MHz after a short delay
* Suitable for use with projects that transmit intermittent signal bursts
* Discrimination of genuine signal from noise
* Repeater chaining possible
* Adjustable delay period
* Adjustable maximum data rate detection
* Solar power with $LiFePO_4$ cell storage
* Up to 200m open-space range with optimised antenna

With a solar panel to keep the internal battery charged, you'll never have to touch it once completed. Get up to double the range you had originally!

cluding buildings, trees and terrain.

Other things to try first

Before building a repeater, there are some simple ways to improve range that may give you the range you need. The first step is to try a better antenna.

Typically, our projects use a short length of wire as the antenna, sized to be one-quarter of the wavelength. This is around 170mm for a 433MHz transmitter or receiver.

Using a commercially-made whip antenna for the transmitter and/or receiver can improve the range compared to the simple wire antenna, as can a longer ½-wave antenna (340mm for 433MHz).

But we must caution you that if your transmitter is close to the 25mW legal limit, using a better antenna (with higher gain) may be illegal. That's because 25mW is the effective radiated power limit, so it takes into account antenna gain. Each increase in antenna gain of 3dB is equivalent to doubling the output power.

So you cannot legally use a +3dBi antenna with devices that exceed 12.5mW transmit power.

Antenna orientation is important too. Having the transmitter and receiver antenna both with the same orientation, eg, both orientated vertically or both horizontally may improve range.

If these changes prove to be impractical or not effective enough, then it would make sense for you to build this repeater.

A repeater is placed in the signal path between the transmitter and receiver.

In this case, the repeater comprises a UHF receiver and UHF transmitter, plus a microcontroller, some memory and a power supply. Once the repeater receives a valid signal, it is stored and

Is this repeater legal to use without a license?

In a word, yes.

You can view the "LIPD" class license for the 433MHz "ISM" band, which applies to everyone in Australia, at: www.acma.gov.au/Industry/Spectrum/Radiocomms-licensing/Class-licences/lipd-class-licence-spectrum-acma

The equivalent document for New Zealand is available at: https://gazette.govt.nz/notice/id/2017-go4089

Note that the New Zealand EIRP limit of -16dBm is the same as the Australian limit of 25mW. It is simply specified in different units.

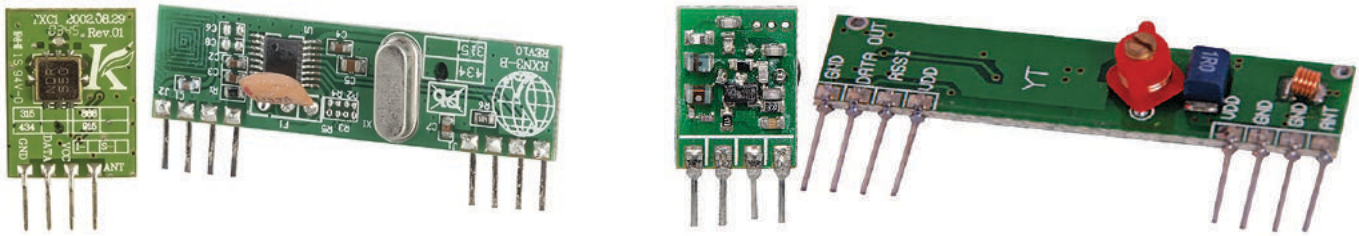
Neither of these documents place any restrictions on the use of the 433/434MHz LIPD band other than the maximum effective radiated power. There is nothing to limit how frequently you may transmit in that band, or how long the bursts can be. And there is no mention of repeaters whatsoever.

Since our repeater uses commercially available 433MHz transmitters, which comply with the power limit, and since it only transmits after the original transmission has ceased, it is entirely legal to operate in Australia and New Zealand.

However, we do not recommend that you use this repeater with any signals which transmit frequently. Typically, you would use it in conjunction with a device that sends a short burst (well under one second) no more frequently than, say, once every 30 seconds. If you used it with a device transmitting rapidly, you could blanket the 433MHz band with transmissions in a 100-200m radius.

The Class License states that: "If interference occurs, the onus is on the user of a LIPD to take measures to resolve that interference, for example by retuning or ceasing to operate the device." (Retuning these devices would be difficult, if not impossible, without specialised equipment).

So keep that in mind, and use common sense when setting up your transmitting device and repeater(s).



The 433MHz Data Repeater is based on commercial transmitter and receiver modules, as shown here. The Jaycar ZW3100 transmitter and ZW3102 receiver are shown on the left with the Altronics Z6900 transmitter and Z6905 receiver at right. They are for all intents and purposes identical; either will fit directly into our PCB.

then after a delay, retransmitted, to be received by the receiver.

This effectively increases the range for the transmission as it can be placed closer to both the transmitter and receiver than they are to each other, and possibly in a more advantageous location (eg, higher up) where there will be fewer obstacles in the way of both signal paths.

Other types of repeaters exist, which operate slightly differently to this one. For example, many repeaters retransmit the received signal on a different frequency.

That prevents conflicts between the transmitter and receiver and allows the repeater to operate with effectively no delay. But the final receiver must be able to receive on the new frequency, so that type of repeater is not 'transparent'.

This repeater retransmits in the same frequency band as the received signal. That means that the final receiver does not need to be modified in any way.

But the repeater has to wait for the end of the transmission before resending. Otherwise, the received and transmitted signals will interfere, and the receiver could even go into a loop, continually retransmitting the same data.

Compatible projects

Some of the projects we have previously published that can benefit from using this repeater:

- the **UHF Remote Switch** (January 2009; siliconchip.com.au/Article/1284),
- the **Versatile 10-Channel Remote Control Receiver** (June 2013; siliconchip.com.au/Article/3811),
- the aforementioned **Driveway Monitor** and **Infrared to 433MHz UHF Transceiver** (June 2013; siliconchip.com.au/Article/3812).

All the projects mentioned above used the standard 433MHz UHF transmitters and receivers sold by Jaycar and Altronics (as shown above).

The Jaycar catalog codes are ZW3100 for the transmitter and ZW3102 for the receiver, while the Altronics catalog codes are Z6900 for the transmitter and Z6905 for the receiver.

This repeater may be able to be used with some other commercial devices transmitting data in the 433MHz band, however, whether it will work depends on the details of those transmissions, so it's hard to say that a particular device will or will not work until you try it.

Keep in mind that you need to use the repeater in situations where it doesn't matter if the receiver could receive two identical packets in a short period.

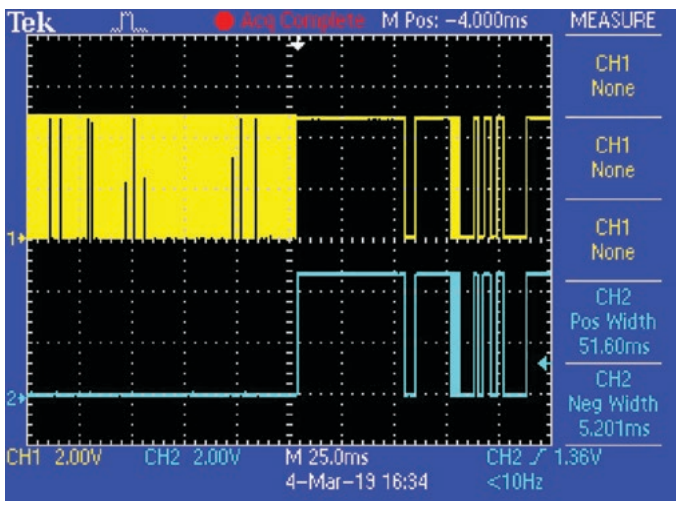
That's because it may pick up both the direct transmission and the repeated transmission in some cases.

In all the projects mentioned above, this should not matter, as the receivers are effectively 'stateless'.

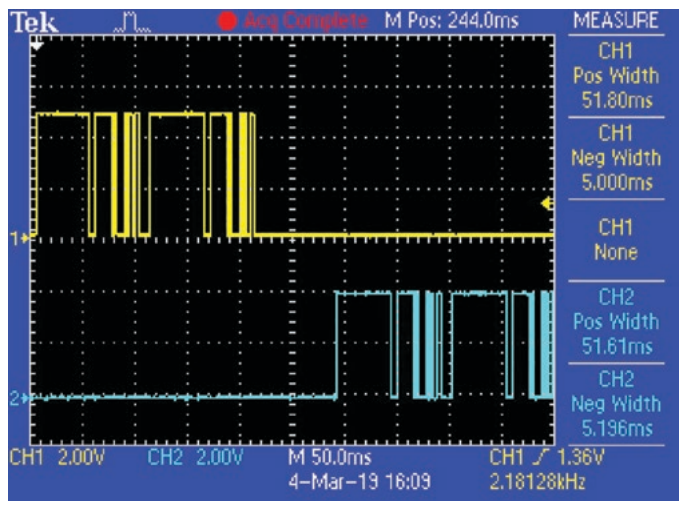
That should be true of many other devices such as weather stations. But again, you will need to try it out to confirm that the receiver's operation is not adversely affected by receiving multiple identical packets.

Presentation

Our repeater is housed in an IP65 sealed box and that means it is suitable for use outdoors, in areas where it could be exposed to the weather.



Screen1: the yellow trace at the top is the output from the UHF receiver, RX1. You can see the high-frequency noise before valid data is received. When there is a received signal, the random signal ceases and the transmitted code is produced instead. IC1 rejects the noise and only accepts the valid code, as shown in the cyan trace below.



Screen2: the yellow trace at the top shows the original signal being received from the source, while the cyan trace at the bottom shows the signal being transmitted by the repeater. You can see how it does not start transmission until it has finished receiving an entire packet, and there is a short delay before retransmission, around 60ms in this case.

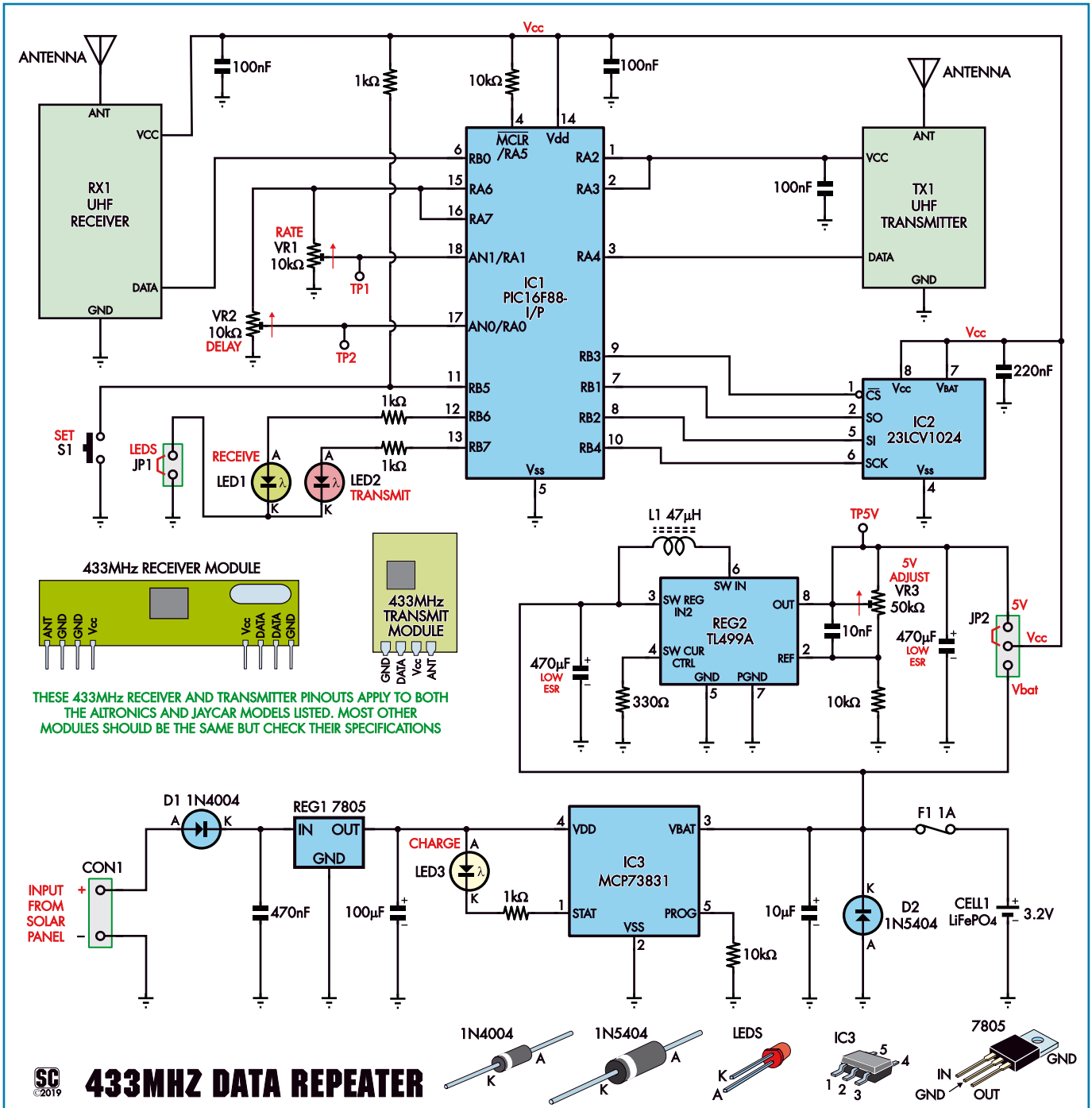


Fig.1: the repeater circuit. Data transmissions are picked up by UHF receiver RX1 and fed to microcontroller IC1's RB0 input. They are then stored in SRAM IC2, and once the transmission is complete, read back out of the SRAM and sent on to UHF transmitter TX1. IC1 then waits for a programmable delay before listening for another transmission. Power from the rechargeable LiFEPO4 cell is stepped up to 5V by REG2, and that cell is charged from a solar panel using charge management chip IC3.

It is designed to be powered from a solar panel and uses a single-cell $LiFePO_4$ rechargeable cell for power storage, so it can be used where there is no mains power available.

This is ideal as you can, for example, mount it up on a pole, where it will have a good 'view' of both the transmitting and receiving units, and it should also get plenty of sunlight to keep the battery charged.

Circuit details

The circuit diagram of the repeater is shown in Fig.1. It's based around microcontroller IC1, the previously mentioned 433MHz transmitter (TX1) and receiver (RX1), a 1024kbit/128kbyte static RAM (IC2), plus power supply parts such as the $LiFePO_4$ charger (IC3) and 5V step-up regulator (REG2).

Microcontroller IC1 monitors the signal from the UHF receiver (RX1), stores the received data in the SRAM (IC2) and then powers up the UHF transmitter (TX1) to send out the stored code that was previously received. IC1

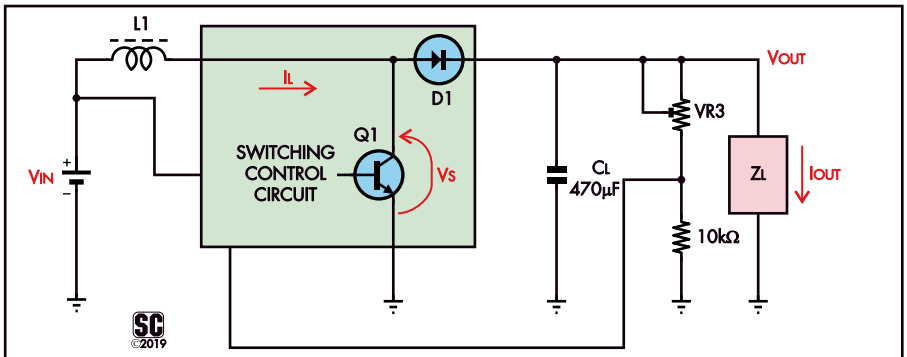


Fig.2: this shows how the boost converter generates 5V to run the micro and UHF transmitter and receiver from the 3.2-4.2V cell. The control circuit pulses the base of internal transistor Q1 which pulls current from the cell through inductor L1, charging up its magnetic field. When Q1 switches off, that magnetic field collapses, D1 is forward-biased and C_L charges up to 5V. This is regulated by feedback to the control circuit via the voltage divider formed by trimpot VR3 and a 10kΩ resistor.

also has two trimpots (VR1 and VR2) that are used to set the maximum data rate and the minimum retransmission delay; more on that later.

Receiver RX1 is powered continuously from the 5V supply so that it can receive a signal at any time. When there is no signal to be received, its data output pin delivers a high-frequency random (noise) signal. That is due to the automatic gain control (AGC) in the receiver increasing gain until it is receiving a signal, even if that signal is just amplified noise.

When there is an actual 433MHz signal to receive, the AGC reduces the receiver's gain to prevent internal clipping, ie, so it is not overloaded due to excessive gain. Since the AGC gain varies at a relatively slow rate, when the 433MHz signal transmission stops, the receiver output will be low for a few hundred milliseconds before the AGC action increases the gain sufficiently to produce noise again.

The 433MHz transmitter and receiver use an elementary modulation system, known as amplitude shift keying or ASK. When its input is high (one), the transmitter produces a 433MHz carrier. When its input is low (zero), the 433MHz carrier transmission stops.

The data rate is usually fast enough that the receiver gain does not vary significantly during the burst, even though during the zero bits, there is no carrier.

There are various schemes which exist to avoid having long periods of all 0s or all 1s, regardless of the data being transmitted, to help in cases like this. One such scheme is Manchester encoding, where each bit is encoded as either a low (0) then a high (1), or a high (1) then a low (0), at a fixed rate. The UHF transmitter and receiver pair can transfer data at up to 5kbits/second using Manchester encoding.

Distinguishing signal from noise

The receiver's AGC action poses challenges for our software, since it needs to be able to distinguish a series of zeros and ones that form part of a genuine data transmission from the zeros and ones that result from the amplified noise in the receiver, when there is no signal present.

IC1 monitors the signal from the UHF receiver at its RB0 digital input (pin 6). Each time the voltage level changes, it decides whether it is just due to noise or a valid data signal. Valid data is determined by comparing the received data rate to the maximum rate setting.

This is set using VR1, which also varies the voltage at test point TP1. With TP1 at 0V, the maximum data rate is 233bps, and with TP1 at 5V, the maximum data rate is 5kpbs. Intermediate voltages give intermediate maximum rate values.

If the incoming data rate is higher than the rate setting of VR1, the data is assumed to be noise and is rejected as invalid (see Screen1).

If the data rate is less than the maximum data rate setting, the data is considered valid and so it is stored in memory. As soon as the data rate exceeds the maximum rate setting, it is assumed that the transmission is complete and so the data which has been stored is then transmitted.

This is done by reading the data out of the RAM and feeding it to digital output RA4 (pin 3) of IC1 at the same rate that it was received. At the same time, TX1, the UHF transmitter is powered up and transmits this stored data (see Screen2).

IC2 is the memory that is used to store the data. It is a 1024kbit random access memory organised as 128k x 8-bit bytes. The memory is read and written using via a Serial Peripheral Interface (SPI).

When writing, data is sent to the SI input of IC2 (pin 5) from the SDO (pin 8) output of IC1, one byte at a time. When reading, data is sent from the SO output of IC2 (pin 2) to the SDI input (pin 7) of IC1; again, one byte at a time. In both cases, the data is clocked by a signal from the SCK (pin 10) of IC1, which is fed TO the SCK input of IC2 (pin 6).

The memory SPI interface is enabled by a low level at the chip select ($\overline{CS}$) input (pin 1) of IC2, which is driven from the RB3 digital output of IC1 (pin 9).

To write to the memory, the $\overline{CS}$ line is brought low and then a write instruction is sent from IC1 to IC2, followed by the memory address to write to. In our application, this is always the first location (address zero). This is a 24-bit address sent as three 8-bit bytes. The seven most significant address bits are always zero since only 17 bits are required to address the 128k bytes in the RAM.

Following this, data can be written, one byte at a time. By default, the address is automatically incremented after each byte of data is written, so bytes are written sequentially to the RAM.

We store the received data as 16-bit values. The most significant bit (bit 15) indicates the received level, low (0) or high (1). The remaining 15 bits are used to store the duration that the data stayed at that level. This period is stored in increments of 4µs, resulting in a 4µs minimum period and 131ms maximum.

Reading data out of the memory is a similar process to writing, except that a different instruction is used and the data is sent in the opposite direction, from IC2 to IC1.

Power saving features

Since we are powering the repeater using solar panels and a small cell for storage, its power consumption must be minimised, especially when idle

and waiting for data. This is done by switching off power to components when they are not required.

The two trimpots, VR1 and VR2, are only connected to the 5V supply when their positions are being read. This is done only during the initial power-up process and when switch S1 is pressed. Any other time, the RA6 and RA7 pins that supply 5V to the trimpots are low (0V), to prevent current flow through the pots. This saves 1mA, which adds up to 24mAh per day.

Similarly, the transmitter (TX1) is off until it is required to send a UHF signal. TX1 is powered directly from IC1's RA2 and RA3 digital outputs (pins 1 & 2); these go high (to 5V) to power TX1. The power saving is considerable since TX1 draws some 10mA when powered and transmitting. This saves 240mAh/day.

IC2 is on standby unless it is being used. So unless there is a valid data being received, it draws just 10µA instead of the 10mA required when it is active. Typically, the memory is only powered twice as long as the transmitter; the first half being the reception period and the second half being the transmission period. This also saves around 240mAh/day.

Microcontroller IC1 typically draws 1.7mA and UHF receiver RX1 draws 2.9mA. The transmit and receive LEDs are powered when TX1 and RX1 are active respectively, and draw about 3mA. The LEDs can be disconnected using a jumper shunt (JP1) to save power if they are not needed. They are mainly provided for testing purposes.

The circuit is powered from a single 600mAH $LiFePO_4$ cell. The quiescent current draw is around 9.4mA, ie, when the transmitter, memory and LEDs are off. This means the cell will last for around 60 hours or 2.5 days when fully charged.

Charging circuitry

The $LiFePO_4$ cell is charged by IC3, which is powered from a 5V regulator (REG1) and this, in turn, is powered from a solar panel. Note that it connects to the circuit via a fuse (F1), which prevents damage if the cell is inserted incorrectly. If the cell is reversed, current will flow through diode D2 and blow the fuse. Diode D1 prevents damage if the solar panel is accidentally connected with the wrong polarity.

IC3 is a miniature single-cell inte-

Parts list – 433MHz Wireless Data Repeater

1 double-sided PCB coded 15004191, 103.5 x 78mm
1 IP65 enclosure, 115 x 90 x 55mm [Jaycar HB6216]
1 600mAh $LiFePO_4$ cell (AA sized, ie, 50mm diameter, 14mm long) [Jaycar SB2305]
1 12V 5W Solar panel [Jaycar ZM9050]
1 panel label (see text)
1 25 x 15 x 10mm powdered iron toroid (L1) [Jaycar LO1242]
1 433MHz ASK transmitter (TX1) [Altronics Z6900, Jaycar ZW3100]
1 433MHz ASK receiver (RX1) [Altronics Z6905, Jaycar ZW3102]
1 PCB-mount tactile momentary SPST pushbutton switch (S1) [Altronics S1120, Jaycar SP0600]
1 2-way screw terminal with 5.08mm spacing (CON1)
1 2-pin header, 2.54mm spacing (JP1)
1 3-pin header, 2.54mm spacing (JP2)
2 shorting blocks/jumper shunts (JP1,JP2)
1 1A M205 fuse (F1)
2 PCB-mount M205 fuse clips (F1)
1 18-pin DIL IC socket (for IC1)
1-2 8-pin DIL IC sockets (optional; for IC2 & REG2)
1 PCB-mount AA cell holder
1 flag heatsink, 19 x 19 x 9.5mm [Altronics H0630, Jaycar HH8502]
1 IP65 cable gland to suit 3-6.5mm diameter cable
6 PC stakes (optional)
4 M3 x 5mm panhead machine screws
1 M3 x 6mm panhead machine screw
1 M3 hex nut
2 4.75mm long #0 panhead self-tapping screws
2 100mm cable ties
1 500mm length of 1mm diameter enamelled copper wire
2 175mm lengths of medium-duty hookup wire ***OR***
2 175mm length of 1mm diameter enamelled copper wire (see text)

Semiconductors
1 PIC16F88-I/P 8-bit microcontroller programmed with 1500419A.HEX (IC1)
1 23LCV1024-I/P 128kB SRAM in PDIP package (IC2) [Mouser, Digi-Key] ***OR***
1 23LCV1024-I/SN 128kB SRAM in SOIC package (IC2) [Mouser, Digi-Key]
1 MCP73831T-2ACI/OT single cell Li-ion/$LiFePO_4$ charger, SOT-23-5 (IC3) [Mouser, Digi-Key]
1 TL499A power supply controller (REG2) [Jaycar Cat ZV1644]
1 7805 5V regulator (REG1)
1 1N4004 1A diode (D1)
1 1N5404 3A diode (D2)
1 Green 3mm high-brightness LED (LED1)
1 Red 3mm high-brightness LED (LED2)
1 Yellow 3mm high-brightness LED (LED3)

Capacitors
2 470µF 16V low-ESR electrolytic
1 100µF 16V electrolytic
1 10µF 16V electrolytic
1 470nF 63V MKT polyester *(code 0.47, 474 or 470n)*
1 220nF 63V MKT polyester *(code 0.22, 224 or 220n)*
2 100nF 63V MKT polyester *(code 0.1, 104 or 100n)*
1 100nF multi-layer ceramic
1 10nF 63V MKT polyester *(code 0.01, 103 or 10n)*

Resistors (all 0.25W, 1% metal film)
3 10kΩ *(brown black orange brown or brown black black red brown)*
4 1kΩ *(brown black red brown or brown black black brown brown)*
1 330Ω *(orange orange brown brown or orange orange black black brown)*
2 10kΩ miniature horizontal mount trimpots (VR1,VR2)
1 50kΩ miniature horizontal mount trimpot (VR3)

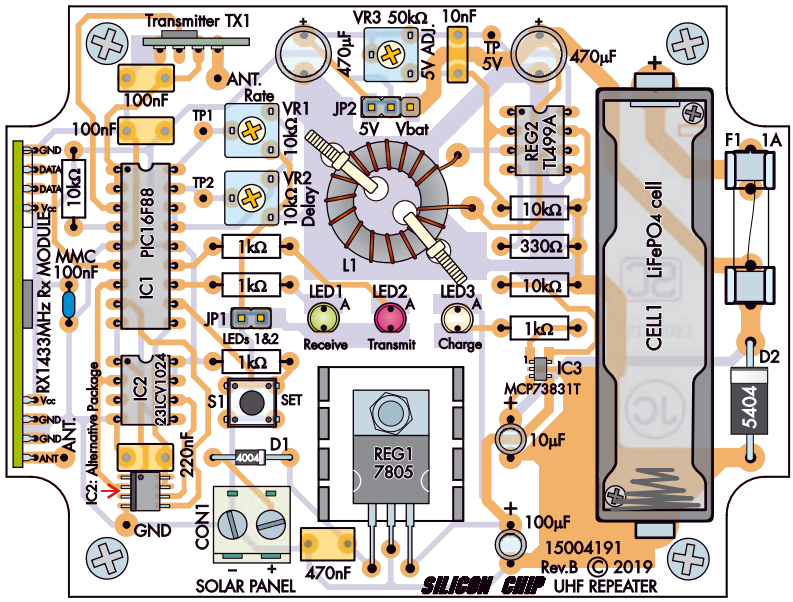
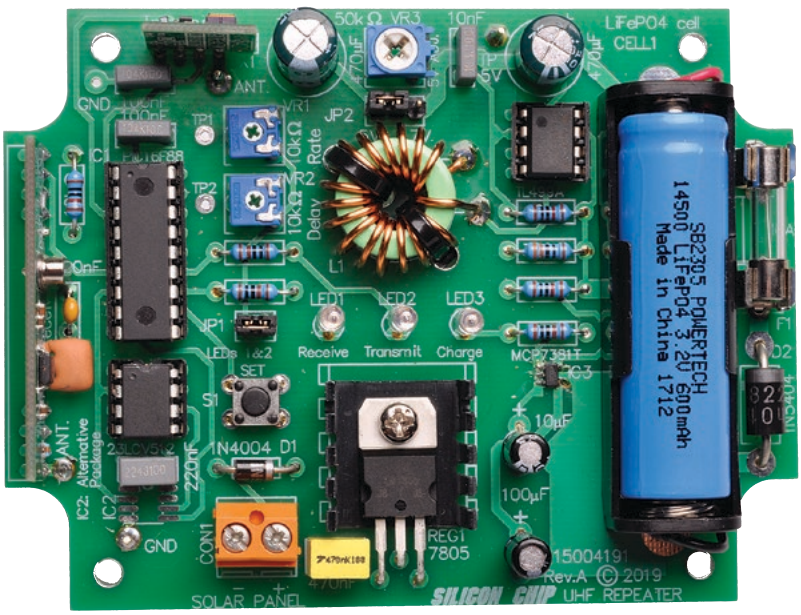


Fig.3: this PCB overlay diagram and the photo below show how the components are fitted to the board. There are two possible locations for IC2, depending on whether you're using the through-hole (DIP) or SMD (SOIC) package version. Be careful to orientate the diodes, ICs, cell holder, transmitter and receiver correctly, as shown here. Some components can be left off if the solar battery charging function is not needed (see the text for details).



grated Li-ion/LiPo charge management controller. It charges the cell at a constant current, up to a charge termination voltage of 4.2V. The charge current is set by the resistance at pin 5. and for our circuit, this is set to 100mA by the 10kΩ resistor. The charge LED (LED3) lights when the cell is charging.

The 433MHz UHF transmitter (TX1) and receiver (RX1) can operate from 2.5-5V. Since the transmitter will have more output power and thus a better range when powered from 5V, rather than the 3.2-4.2V from the $LiFePO_4$ cell, we use a step-up (boost) regulator to generate a 5V to power these modules.

However, the circuit can be built without this step-up regulator, if maximum range is not required. This saves time and money. The rest of the circuit will then be powered directly from the $LiFePO_4$ cell. This would also extend the cell life as the step-up regulator is only around 70% efficient, and the lower supply voltage will also mean that less current is drawn by IC1, IC2, TX1 and RX1.

Jumper link JP2 is used to select whether these components are powered from the 5V boosted supply, or directly from the cell.

The voltage step-up is performed by TL499A switching regulator REG2. It comprises a switching control circuit, a transistor and a series diode. It requires inductor L1 to perform the boost function and a 470µF low-ESR output capacitor for energy storage and filtering.

A simplified circuit showing the operation of the boost converter is shown in Fig.2. Initially, internal transistor Q1 is on and current flow begins to build through the inductor L1 (at a rate limited by its inductance), until it reaches a particular value. This maximum current is set by the resistor connected to pin 4 of REG2.

When Q1 switches off, L1's magnetic field collapses and so current continues to flow to the load and output capacitor C_L via diode D1. This current flow causes a voltage to appear across L1, which adds to the supply voltage (V_{IN}), charging C_L up to a higher voltage than the input supply.

The process continues with Q1 switching on again, once L1's magnetic field has mostly dissipated, and thus the field builds back up until Q1 switches off again.

The output voltage is sampled via a voltage divider comprising trimpot VR3 and a 10kΩ resistor. This determines the proportion of the output voltage applied to pin 2 of REG2, which it compares against an internal 1.26V reference. The duty cycle of Q1 is controlled to maintain 1.26V at the pin 2 input.

Therefore, by changing the resistance of VR3, we can vary the output voltage. The greater the attenuation of this resistive divider, the higher the output voltage must be to maintain 1.26V at pin 2. If VR3 is set to 29.68kΩ, the divider formed with the 10kΩ resistor reduces the output by a factor of 3.97. That means that the output will be 3.97 x 1.26V = 5V.

Should the output voltage rise slightly above 5V, the TL499A will cease switching Q1 until the voltage falls slightly below the 5V level. Should the voltage fall below 5V, the transistor will be driven with a higher duty cycle, to deliver more current to the output and bring it back up to 5V.

Note that the 1.26V reference is only a nominal value and could be any volt-

age between 1.20V to 1.32V, depending on the particular IC. So VR3 makes it adjustable, to allow the output voltage to be set accurately.

Chaining multiple repeaters

As mentioned in the features panel, it is possible to have more than one repeater, to extend the transmission range further. The repeater closest to the source (original transmitter) will send the signal on to the second repeater. When the second repeater sends out its signal, the first repeater must ignore it; otherwise the two repeaters will endlessly retransmit the same packet.

This is prevented by an adjustable delay between the end of each transmission and the unit accepting a new packet. This delay ranges from 50ms to 12.5s and is set using VR2. The voltage at TP2 indicates the delay setting, with each volt representing 2.5s. So for example, if VR2 is adjusted for 2V at TP2 then the delay is 2.5s x 2 = 5s. 0V gives a 50ms (minimum) delay.

Construction

The repeater is built using a double-sided PCB coded 15004191 which measures 103.5 x 78mm. It fits in an IP65 sealed box measuring 115 x 90 x 55mm. Use the PCB overlay diagram, shown in Fig.3, as a guide during assembly.

Start by soldering the battery charger, IC3. This is in a small five-pin SMD package. The correct orientation is evident since it has two pins on one side and three on the other. Tack solder one of the pins (ideally, at upper right) then check its orientation and solder the diagonally opposite pin.

Then proceed to solder the remaining pins, and refresh the first joint with a bit of added solder or flux gel.

If you accidentally bridge the three pins which are close together, add a little flux paste and then clean up the bridge with the application of some solder wick.

The PCB has the option to use a DIP (through-hole) or SOIC (SMD) package for the memory chip (IC2). Only one type should be installed. If using the SOIC package, solder it next, using a similar procedure as described above. But first, make sure that its pin 1 dot or divot is at upper left, as shown in Fig.3. It should also have a bevelled edge on the pin 1 side.

The SOIC package for IC2 is larger than that of IC3, so you should find it a little easier. Again, any accidental bridges can be cleaned up with flux paste and solder wick.

Install the resistors next. They are colour coded with the resistance value as shown in the parts list. A digital multimeter should also be used to check the resistor values, as the colour codes can be hard to read.

Fit the diodes next, making sure to insert them with the correct polarity, ie, with the striped ends facing as shown in the overlay diagram. D2 is considerably larger than D1.

We recommend soldering an IC socket for IC1. The remaining ICs (including IC2, if using the DIP package version) can be fitted via an IC socket or soldered directly in place, which would give better long-term reliability. Take care with orientation when installing the socket(s) and ICs. Additionally, make sure that IC2 and REG2 are not mixed up.

Next, there are six optional PC stakes to install. These make wiring connections and test point monitoring easier. These are located at TP5V, GND, TP1, TP2 and one each for the antenna connection of RX1 and TX1.

The capacitors should be mounted next, starting with the 100nF multilayer ceramic capacitor next to UHF receiver RX1, then following with the MKT polyester types, none of which are polarised. Follow these with the electrolytic types, which must be installed with the polarity shown; the longer lead goes into the pads marked with a "+" sign, towards the top of the PCB.

REG1 can be now fitted. It is mounted horizontally on a heatsink. Bend the leads so they fit the PCB holes while the mounting hole lines up with the hole on the PCB. Sandwich the heatsink between the regulator and PCB and do up the screw and nut before soldering the leads.

Trimpots VR1 to VR3 are next. VR1 and VR2 are 10kΩ and would typically be marked with 103. VR3 is 50kΩ and may be marked as 503. Then install the LEDs, LED1 to LED3. In each case, the anode (longer lead) goes to the pad marked with an "A" on the PCB. The bottom of the LEDs should be about 5mm above the PCB surface when soldered in place . You can then fit pushbutton switch S1.

Install the 3-way and 2-way SIL headers now, for JP1 and JP2. Then fit the 2-way screw terminal, CON1, with the wire entry holes end toward the bottom PCB edge.

L1 is wound using 17 turns of 1mm enamelled copper wire on a 25mm diameter powdered iron toroidal core. These turns should be wound neatly around the perimeter, as shown in Fig.3. Remove the enamel from the ends of the wires using a hobby knife so you can tin them and then solder them to the PCB pads shown. The core is held in place with two cable ties that loop through PCB holes, as shown.

The battery holder must be orientated as shown (red wire to +) and secured to the PCB using two self-tapping screws through the cell holder and into the slotted holes on the PCB. Cut the wires from the battery short and terminate them to the PCB.

Insert the fuse clips for F1, making sure that the end stops in the clips are facing to the outside. Before soldering them, insert the fuse so that the clips are correctly aligned, for good contact with the fuse.

Finally, the UHF transmitter and receiver can be mounted. These must also be orientated correctly. The pin markings are printed on the transmitter module. Orientate the antenna pin connection on the transmitter and receiver so that they are adjacent to the antenna connections on the PCB.

You have two options for the antennas: either use 170mm lengths of hookup wire coiled inside the box or, for better range (>40m), 170mm-long lengths of stiff enamelled copper wire protruding from the box.

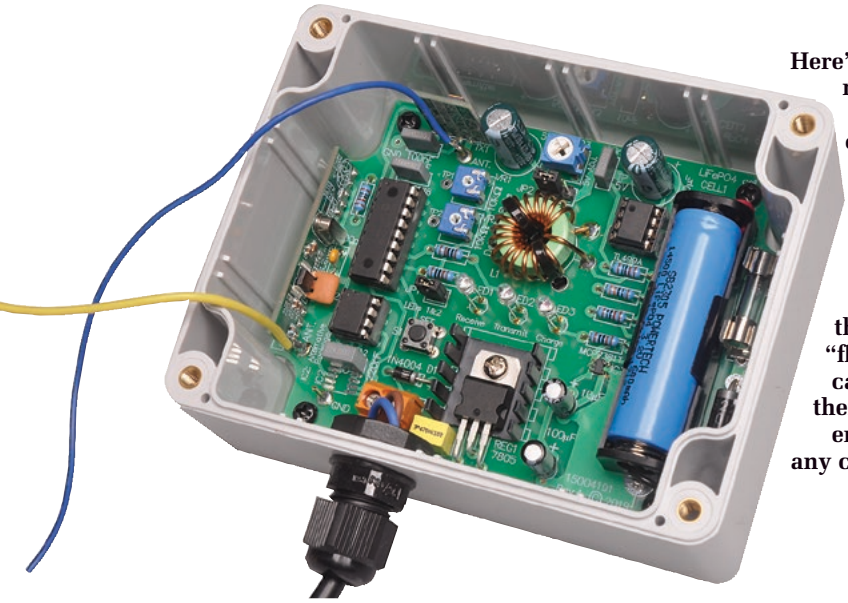
The extra 5mm in the lengths specified in the parts list is to give you enough wire to solder to the antenna terminals (for the hookup wire) or to bend over at the tip (for the enamelled copper wire).

Having chosen which antenna wire you want to use, cut the appropriate lengths and solder them to the antenna PC stakes, or directly to the antenna pads if you are not using PC stakes.

Note that you will need to scrape some insulation off the end of the enamelled copper wire (eg, with a hobby knife) so that you can tin and then solder it to the board.

Mounting it in the box

There is not much work required to mount the board in the box. We drilled a hole in the side for the cable gland required for the solar panel wiring.



Here's how it looks mounted in its waterproof case. The blue and yellow wires are the 170mm-long transmitting and receiving antennas – they can be left "floating" in the case but ensure there are no bare ends to short to any components or to the PCB.

This hole is 25mm up from the outside base of the case opposite CON1. If you only require a UHF transmission range of less than 40m, the antenna wires can be bent around the inside perimeter of the box.

For maximum transmission range (up to 200m), the stiff receiver antenna wire should pass through a small hole in the upper edge of the box, and the receiver wire similarly should pass through a small hole in the lower edge of the box.

Once it's through, bend the tips over to form small 3mm loops. That prevents you poking your eye out on the otherwise sharp end.

1mm wire is used so that the wire is stiff enough to stay straight. The wire exit holes should then be sealed with a neutral cure silicone sealant.

The repeater PCB is held inside the case by M3 screws that go into the integral threaded bushes in the base of the box.

The Neoprene seal for the lid needs to be placed inside the surround channel and then cut to size. The start and finish gap in this seal should be along the lower long edge of the lid.

Labelling it

To produce a front panel label, you have several options.

For a rugged label, mirror the design and print it onto clear overhead projector film (using film suitable for your type of printer). This way, the ink will be on the back of the film when the label is affixed. Attach with clear silicone sealant.

There are alternatives such as "Dataflex"and "Datapol" labels for use with inkjet and laser printers – you'll find more information and direct links to these products at: **www.siliconchip.com.au/Help/FrontPanels**

Solar panel or mains power

We used a 12V 5W Solar panel to power the unit. A 6V panel would be more efficient, since we are reducing the voltage down to 5V. However, 6V panels aren't easy to find. The panel power rating only needs to be 1W.

If you want to run the unit from mains power, a 9V plugpack could be connected to CON1 instead.

Make sure the plugpack is out of the weather, with only the low voltage wires going to the repeater.

In this case, IC3 and the $LiFePO_4$ cell are not required, although you could leave them in so that the unit will run even during power outages (assuming the transmitting and receiving units are also battery-powered).

If you're leaving off IC3, you could also omit F1, D2, LED3 as well as IC4 and its associated parts. The 5V output from REG1 could then be directly used to power the circuit by connecting a wire link from the regulator output to the 5V terminal at JP2.

Setting up

It is essential that the shunt is not placed on JP2 until VR3 is adjusted to for 5V at the output of IC4. To do this, insert the $LiFePO_4$ cell into the holder and measure voltage between the GND and TP5V PC stakes. Adjust VR2 for a reading of 5V.

Installation

The repeater should be mounted in a location that will give good reception of the original UHF signal. The LED indicators (LED1 and LED2) will let you know if the signal is received and retransmitted if a shunt is installed on JP1.

VR1 must be adjusted so that the receive LED does not flash at all, or at least not too often, when no signal is being received. But if it's adjusted too far, the repeater will not work, so you need to check that it is still retransmitting valid data.

To achieve this, initially set VR1 fully clockwise and press S1 so that the VR1 setting is updated. More of the random signal noise will now be detected and the receive LED will flash now and then, followed by the transmit LED. Adjust VR1 anticlockwise a few degrees and press S1 to again update the setting. Check that the repeater retransmits correctly.

If the repeater operates correctly, try further anticlockwise adjustment. The final adjustment will be a compromise between reliable repeater operation and noise rejection from the UHF receiver.

Adjusting VR1 too far anticlockwise will prevent successful repeater operation.

VR2 should be set fully anticlockwise if you are using a single repeater. If you are using multiple repeaters, set VR2 on all repeaters fully clockwise, giving a 12.5s delay. If your transmitter can send signals more often than this, you will need to experiment with the maximum clockwise rotation of VR2 that will still cause all valid packets to be relayed.

Remember that the settings for the VR1 and VR2 trimpots are only read by IC1 when first powered up and when S1 is pressed. LED1 and LED2 light when S1 is pressed, to acknowledge that the settings have been updated.

Once you've finished adjusting VR1 and VR2, you will need to check whether the ultimate receiver is correctly decoding the retransmitted code from the repeater(s). If not, you may need to move them.

You can then permanently mount the repeater(s). This is done using the mounting holes provided in the box corners.

These holes are accessible when the box lid is removed.

Alternatively, you could use a bracket and attached this to the box using the box mounting holes.

Avoid drilling extra holes in the box as this could compromise its watertight seal. SC

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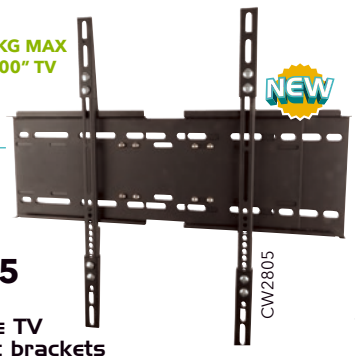

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tech talk

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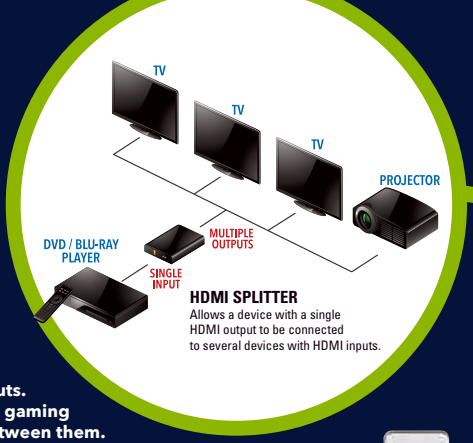
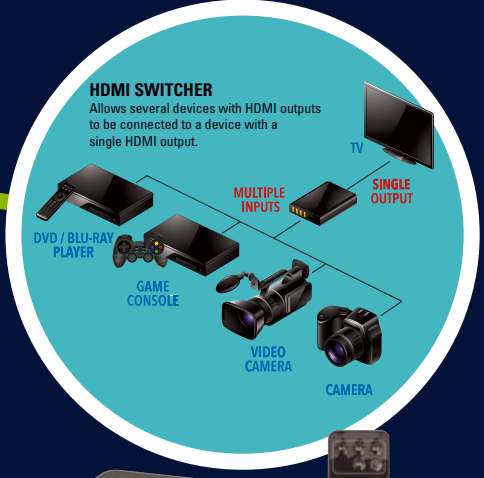


HDMI SPLITTER
Allows a device with a single HDMI output to be connected to several devices with HDMI inputs.



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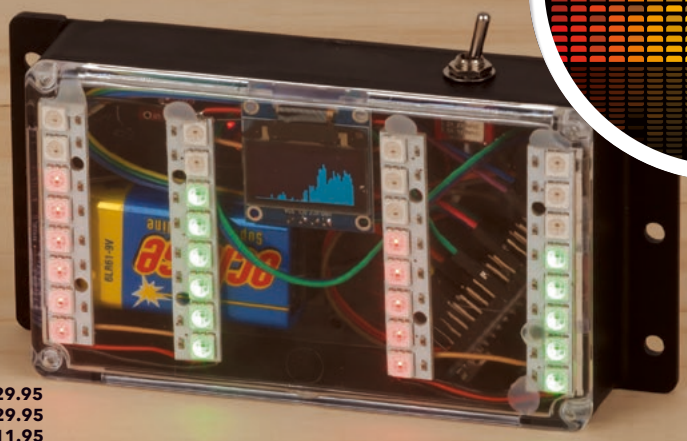
PROJECT: music beat bar



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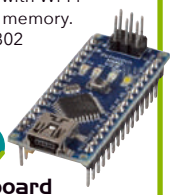

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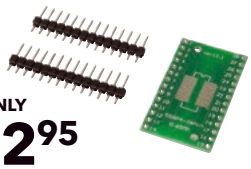

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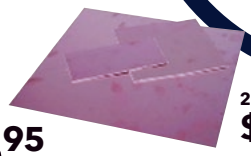

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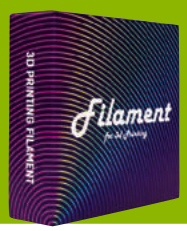

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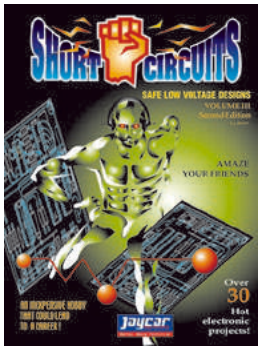

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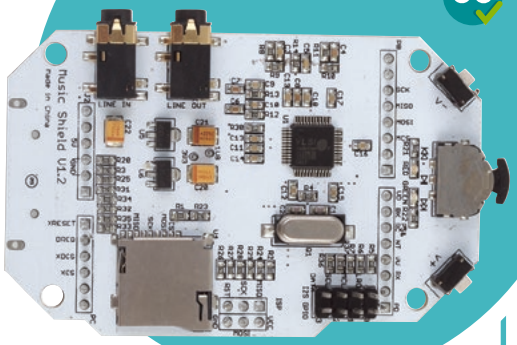

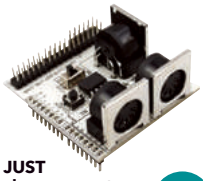

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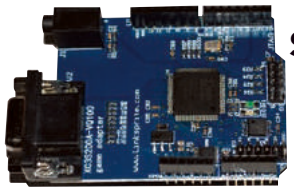

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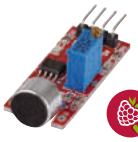

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SERVICEMAN'S LOG

Samsunk – or the dishwasher that wouldn't

Dave Thompson

I've owned many Samsung products over the years and no wonder; this South Korean manufacturer has their fingers in many pies. They've been around for years but more recently have become known as innovators and leaders in the field of consumer electronics, especially phones, tablets and TVs.

Like many other companies, they've had the odd swing-and-a-miss, but in general, they make quality products.

I was mindful of this when we renovated our house a few years ago and decided on some shiny new Samsung appliances for the kitchen. For the dishwasher, we chose a Samsung Waterwall over appliances made by more well-known brands that specialise in kitchen appliances.

It certainly wasn't the cheapest option, but it looks the part with its minimalist, brushed stainless-steel exterior and slick, futuristic blue multi-LED display buried behind the door panel and peeking through tiny, patterned holes laser-cut into the facia. Very cool and just the thing for the modern kitchen.

However, it is not without its problems. From day one, when the wash program was set and the door closed, the front display would often show all 8s instead of the time remaining. A light tap on the door beside the display usually got it back to normal. I suspected a loose connection or dry joint perhaps.

We'd spent a long four months rebuilding and renovating the kitchen while cooking on a gas range, having dinner on crates and washing our dishes in a bucket. I wasn't keen to tell the wife that mere weeks after installing the dishwasher, I'd have to pull it out again and either get it repaired under warranty or disassemble it and repair it myself.

For the time being, we could live with such a minor fault; after all, its operation wasn't adversely affected, and the display glitch only manifested itself roughly half the time anyway.

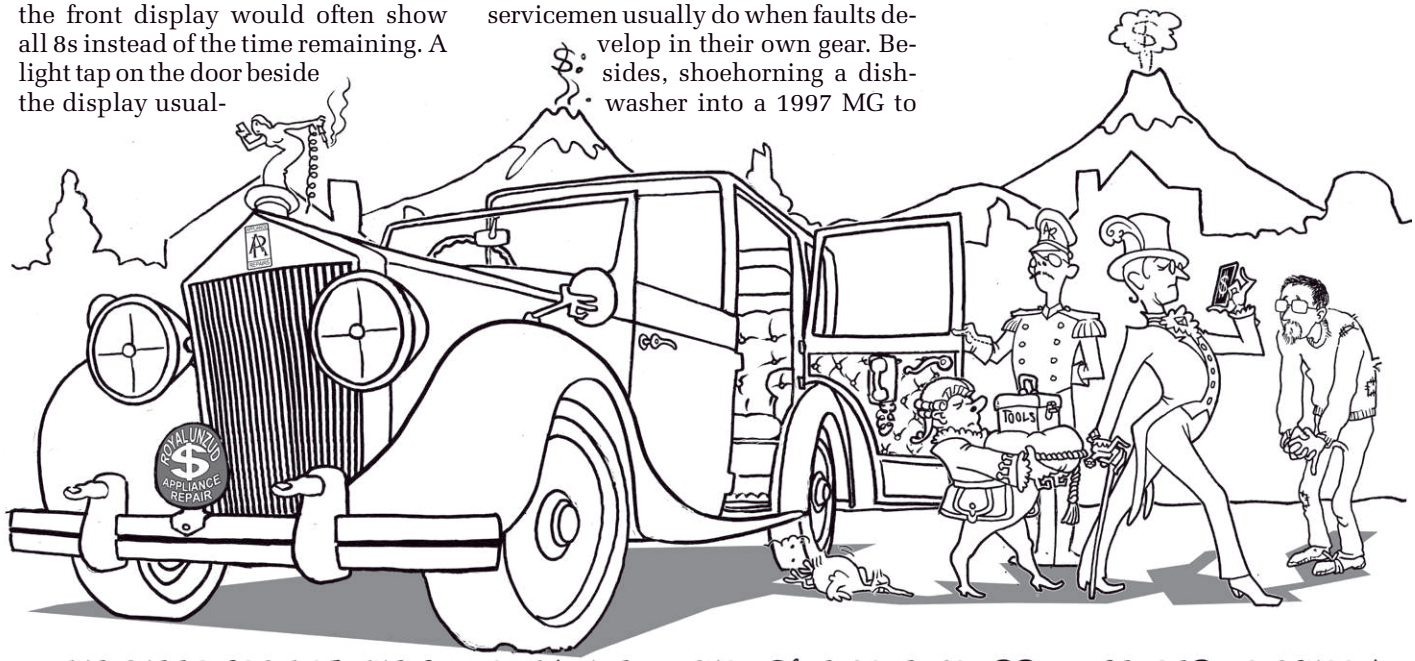
I did log the fault with the relatively good online registration/warranty system and was advised by some virtual assistant to take the dishwasher to an accredited repair agent — advice that I ignored because, well, that's what servicemen usually do when faults develop in their own gear. Besides, shoehorning a dishwasher into a 1997 MG to transport it to an appliance-repair guy across town just isn't feasible!

The dirty water thickens

That was two-and-a-half years ago, and aside from that small fault, the dishwasher performed flawlessly. However (there's always a however!), a few months ago, I started noticing that the bottom rack of dishes (usually the most soiled in any dishwasher layout) were not being cleaned properly.

This would happen once every ten or so washes, but over time it started happening more often, until almost every wash cycle ended up with dirty dishes in the bottom tray.

I was actually becoming a bit annoyed. It's a story all too familiar with modern appliances, conveniently failing just outside of the two-year warranty period. I messaged the virtual assistant on Samsung's website and



~THE SHEER COST OF THE CALLOUT (I KNEW I SHOULD'VE GONE TO APPLIANCE-REPAIR SCHOOL).

Items Covered This Month

- The dishwasher that wouldn't
- RF interference at the end of the rainbow
- Marantz 1120 amp repair
- Vacuum cleaner tripping RCD

Dave Thompson runs PC Anytime in Christchurch, NZ.

Website: www.pcanytime.co.nz
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received the same advice as before. I don't know how they expect people to be dragging dishwashers all over town but we still don't have the capacity to easily do that.

The other option was to have a technician come out and have a look at it. Two things deterred me: one, the sheer cost of the callout (I knew I should've gone to appliance-repair school) and two, the guys I rang up and talked to had no experience with a Samsung Waterwall dishwasher. Perhaps these appliances were still a bit too new.

Desperately seeking solutions

My next stop was the good old interweb; somebody must have come across this problem before!

And it seems they had; forums were ablaze with the flaming posts of disgruntled Samsung Waterwall owners. In fact, some posters were trying to scrape up support for a class-action type product recall, while others just bemoaned Samsung and everything connected with the company. Most stated they'd never buy Samsung again.

Crikey! I wish we'd seen this before we bought the thing, but then again, these posts weren't there at the time (note to self: must mend the time machine, then go back in time and choose a different dishwasher. Also maybe do something about that Hitler guy).

It is worth noting that forums tend to disproportionately magnify any problems because they are being viewed through the lens of people whose first instinct is to get online and vent their spleen. It's as if they are on some kind of modern-day crusade, using their collective rage to try to take Samsung down and thus salve their consumer remorse for making a poor purchasing decision.

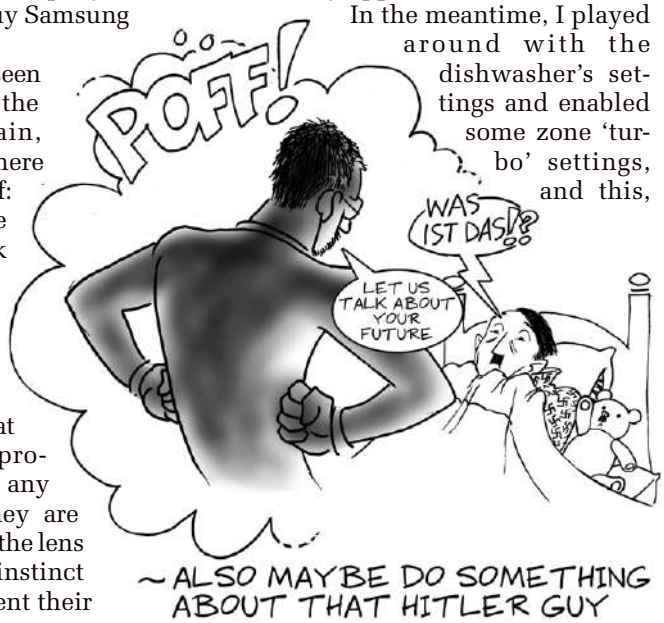
To put this into perspective, Samsung has sold hundreds of thousands of our model of dishwasher alone, yet 20 people grumbling about it in a forum can make it look like this machine is the worst thing ever made. Like I've always said: the best thing about the internet is that it gives people a voice; the worst thing about the internet is that it gives people a voice.

I did my usual research on the web, first looking for similar problems and solutions for my model of dishwasher. When I found nothing but other people griping without offering any clues to the cause (or better still a fix), I cast my net wider into other models, and used broader and broader search terms, in a quest for anything relevant.

Frustratingly, I found nothing constructive. I assumed at the time that this was because of the relatively new technology being used and the lack of repair reports filtering through to end-users via the internet.

I couldn't find any service manuals online, either. While there were plenty of user manuals available for download, they offered nothing but the usual operating advice and a basic (ie, useless) troubleshooting guide. What I needed was a full service manual. While I discovered a site advertising one for sale, it was too expensive. Given time, free service manuals must eventually appear online.

In the meantime, I played around with the dishwasher's settings and enabled some zone 'turbo' settings, and this,



in conjunction with pre-rinsing the dishes and trying different powders and pellets, helped clean the bottom rack a bit better.

Still, it rankled that I had to wash the dishes before I put them in the dishwasher. After all, it was supposed to be washing dishes for me — not the other way around (you had one job, dishwasher)! An actual fix or explanation of the cause of this problem would be nice to have.

Now the dishwasher is complaining too

So, that was the situation until a new fault appeared just a few weeks ago. This manifested as a grumbling noise just after starting the wash cycle; usually. I noticed this immediately since its operation is normally extremely quiet.

My first thought was perhaps a pump bearing had failed, but I was just guessing; I'd need more information on how it worked to be even in the troubleshooting ballpark. But the faults were likely related.

I went back to the web and once again waded through the familiar wasteland of the forums, though this time, I started seeing a link to a YouTube video purporting to show a relatively simple fix for this very problem.

There was also more incidental information, so it appeared that between now and when I first started looking, a lot more people had experienced similar problems and some valid repair information was finally starting to appear. I also found a link to a free service manual, which I immediately downloaded. It was then off to YouTube to check out this 'fix' video.

The guy in the video, who appeared to be American, described the exact problem I was having and on a very similar model.

This was fortuitous because there are dozens of different models in the Waterwall range (which is typical given the different regional markets) so it was a pleasant surprise that this repair video appeared to apply to my model as well.

Reinventing the (water)wheel

To explain the problem properly, I have to also explain how this new-fangled Waterwall system works. In a typical dishwasher, rotating, freewheeling booms with angled spray jets in the top side are driven by water pressure

and these spin beneath the dish racks and the blasting, hot and soapy water cleans then rinses the dishes.

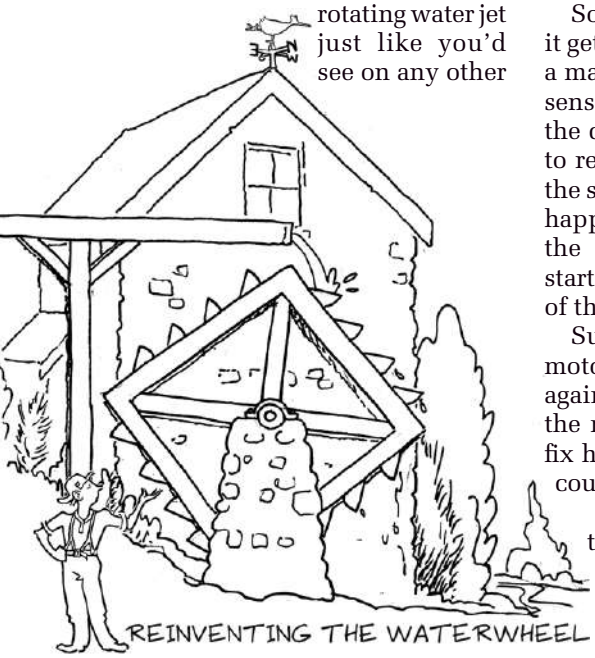
There are usually two of these rotating arms, one for the bottom rack and one for the top. It is a simple system, and while there is obviously other stuff going on (water heating, pumping, soap tray opening and drying cycles), that isn't relevant here.

In the Waterwall system, there are two horizontally-mounted 'vanes' sitting at opposite ends and spanning the bottom of the washing chamber; one is fixed at the far end, while the front one is mobile and driven backwards and forwards by a stepper motor.

The front vane is clipped to and travels along a polished metal beam running down the middle of the chamber floor, and has a sharp curve on the edge, facing the rear vane. The fixed back vane has a series of high-pressure water outlets equally-spaced along its length, pointing parallel to the floor and aiming at the front vane's curved surface.

The idea is that water is blasted from the rear vane into the front vane, which creates the titular "water wall" as that vane traverses the chamber and this is what mainly cleans the bottom rack of dishes. There is now a video on YouTube showing this operation using three different cameras mounted in the dishwasher, which explains the process better than I can.

There are two other racks in the dishwasher; one middle rack for cups and glasses and a cutlery tray at the very top, each with their own standard rotating water jet just like you'd see on any other dishwasher. These traditional jets in my dishwasher clean those upper trays just fine; it is just the Waterwall system that is failing to clean the bottom tray properly.



From my research, I discovered that if I'd gone down the more well-trodden route of having a technician come out, he would likely have gone through the Samsung-recommended protocols of swapping out a couple of pump motors, a stepper motor and gearbox, a sensor array and finally the main PCB, all at our considerable cost.

This unsuccessful repair scenario was a much-repeated story posted in the various forums, and I have no doubt this would have been the case with us too. None of these 'fixes' would have resolved our problem.

Finally figuring it out

From the video, I learned that the noises I heard on cycle start were the front vane moving along its usual travel path to check nothing was impeding it before the wash cycle started.

Indeed, one of Samsung's helpful suggestions in their troubleshooting guide is to ensure that nothing is protruding through the bottom of the lower rack, as this can stop the vane moving and cause possible damage.

The front vane on my dishwasher was moving OK; it just didn't know when it hit the other end, so the poor old motor kept spinning and the gears kept slipping, causing the noise. The vane eventually gives up trying to move and just stops where it sits, explaining the noise and the lack of cleaning.

So, what tells the vane to stop when it gets to the end of its travel? Simple: a magnet mounted on the vane hits a sensor mounted beneath the floor of the chamber, and this tells the motor to reverse and send the vane back to the start position. I proved this wasn't happening by opening and closing the door just after and during the start cycle, to check on the progress of the vane.

Sure enough, it hit the end and the motor kept on going if I shut the door again. Obviously, this wasn't doing the motor or gearbox any good, so a fix had to be implemented before we could continue using the dishwasher.

All the sharp troubleshooters out there will have already deduced that there are two possible causes of this fault, the magnet and the sensor.

Fortunately, by this time I'd found the service manual and could test the sensor (and many other parts for the system) by using codes from the book to run the different components individually, without having to waste a lot of time waiting for a cycle to complete.

Having this information was well worth the hassle of finding the service manual.

By holding down certain buttons and pressing others, I could initiate the vane travel test, and by placing a magnet near where the vane's magnet would sit, I could stop it from moving any further. This proved the sensor was working, and that the magnet is the problem; however, I already knew this because of the YouTube video.

The guy in that video explained that the plastic-coated iron magnet attached to the vane gradually loses its strength due to the constant heating and cooling cycles.

His fix was to replace the magnet with a much stronger rare-earth or neodymium type. He simply took out the old magnet, which is mounted in a removable plastic housing, and glued a whopping great rare earth one in its place. His dishwasher then cycled perfectly, and he sat back and basked in the adoration of a grateful public.

In the end, a simple repair

I didn't have a rare-earth magnet of that size in stock, so I tried various solutions, such as removing some from an old hard drive and cutting them down to suit, but wasn't overly successful.

I discovered that cutting these magnets with anything severely diminishes their strength. Putting two smaller neodymium magnets together side by side also didn't work well, so I went looking for alternatives.

Jaycar has some in various sizes, but those few with magnetic strength mentioned were only rated at most N35, which is probably not strong enough. I hit my usual go-to hardware-stores' websites and found that both places I frequent had various magnets listed at a reasonable cost.

I ended up with a packaged pair of N42-rated 'door' magnets, just the right size at 25 x 7mm and for the princely sum of just $25. I figured I could use one and have a spare for when the problem inevitably returns.

Unlike the guy in the video, I kept the original magnet holder and simply shaped it a little to accommodate

RF INTERFERENCE AT THE END OF THE RAINBOW

the bigger magnet. I firmly tacked it in place using some of the food-grade silicone sealant that I had left over from the kitchen reno and gave it a good 24 hours before re-assembling the holder to the vane and the vane to the dishwasher.

After completely resetting the dishwasher by powering it off at the breaker and powering it up again, I ran a test cycle using the magic codes. It worked perfectly, without any nasty noises and the bottom rack of dishes are now cleaning correctly. The display still glitches now and then, but $25 is an excellent repair bill, given it could have been much, much higher.

Of course, the display is still a bit flakey as that is an unrelated problem. But I'm so relieved to have clean dishes again that I'm leaving that fix for another time...

RF interference at the end of the rainbow

D. P., of Faulconbridge, NSW went on a bit of a wild goose chase to try to track down the source of some strong radio frequency interference. It took some time but not only did he figure out where it was coming from, he also managed to shut the source down. Here is how...

The Amateur Radio fraternity maintains repeaters on various bands (mainly VHF and UHF). These repeaters are usually set up and maintained by local amateur radio clubs and are for the use of all licensed amateurs. The idea is that one can get good communications from low-lying or other difficult locations by virtue of the prime (radio) location of the repeater.

The repeaters have different input and output frequencies and are located on the best high point that the club can organise. For the higher bands, a single antenna usually serves for both the receive and transmit signals.

You may wonder how that is possible. The received signal is typically tenths of a microwatt, while the transmitter output is usually 50W or more, and the frequency separation between the receive and transmit frequencies is relatively small (600kHz, in the case of VHF repeaters).

The secret is cavity resonators. They have a very narrow passband, with extremely high attenuation outside of it. They can be connected in series for even better filtering. Most VHF repeaters have three or more cavities, providing a high degree of isolation between the transmitter and receiver. Other devices such as hybrid rings are sometimes also used to enhance the effect of the cavities.

A few years ago, I joined the repeater committee of my local club in the Blue Mountains, west of Sydney. For some time, the club's VHF repeater had been plagued by interference. The origin of the interference was unknown, although it had been positively established that it was coming in on the antenna, and that nothing in the building was causing it.

This had been established partly by monitoring the repeater input frequency with various receivers at different locations. The interference could be heard well away from the repeater.

The interference consisted of bursts of a nasty rasping noise and made the repeater pretty much useless. The interfering signal was strong enough to open the receiver squelch at regular intervals, triggering the repeater, retransmitting the horrible noise. The constant bursts of noise were so annoying that few people monitored the repeater any more.

One of our club members had a job as an engineer in one of the telecommunication companies. He became interested in the interference problem and connected a VHF antenna to a spectrum analyser at work. The interfering signal was plainly visible, and one of our member's colleagues said he thought it was a pager signal, albeit grossly distorted and "chopped up".

Strangely, though, it was not on any established pager frequency; it was definitely in the VHF Amateur band. Actually, it was centred adjacent to our repeater input frequency with its sidebands regularly intruding into our repeater input passband. It was at these times that the interference occurred.

I tried listening to the pager frequencies on a separate receiver while monitoring the repeater output but I was initially confused because sometimes the pager data seemed to be triggering the repeater, sometimes not.

Telstra used three pager frequencies at the time. These same frequencies were transmitted simultaneously from stations dotted around the country. Signals on one of these frequencies were definitely unrelated to the interference, but the other two seemed to both be contributing to it.

Eventually, by using two receivers, we discovered that it was when both of these frequencies were active simultaneously that the interference occurred.

So it seemed to be some kind of intermodulation effect, but where was it occurring? It was not in our repeater, since we had established that the in-

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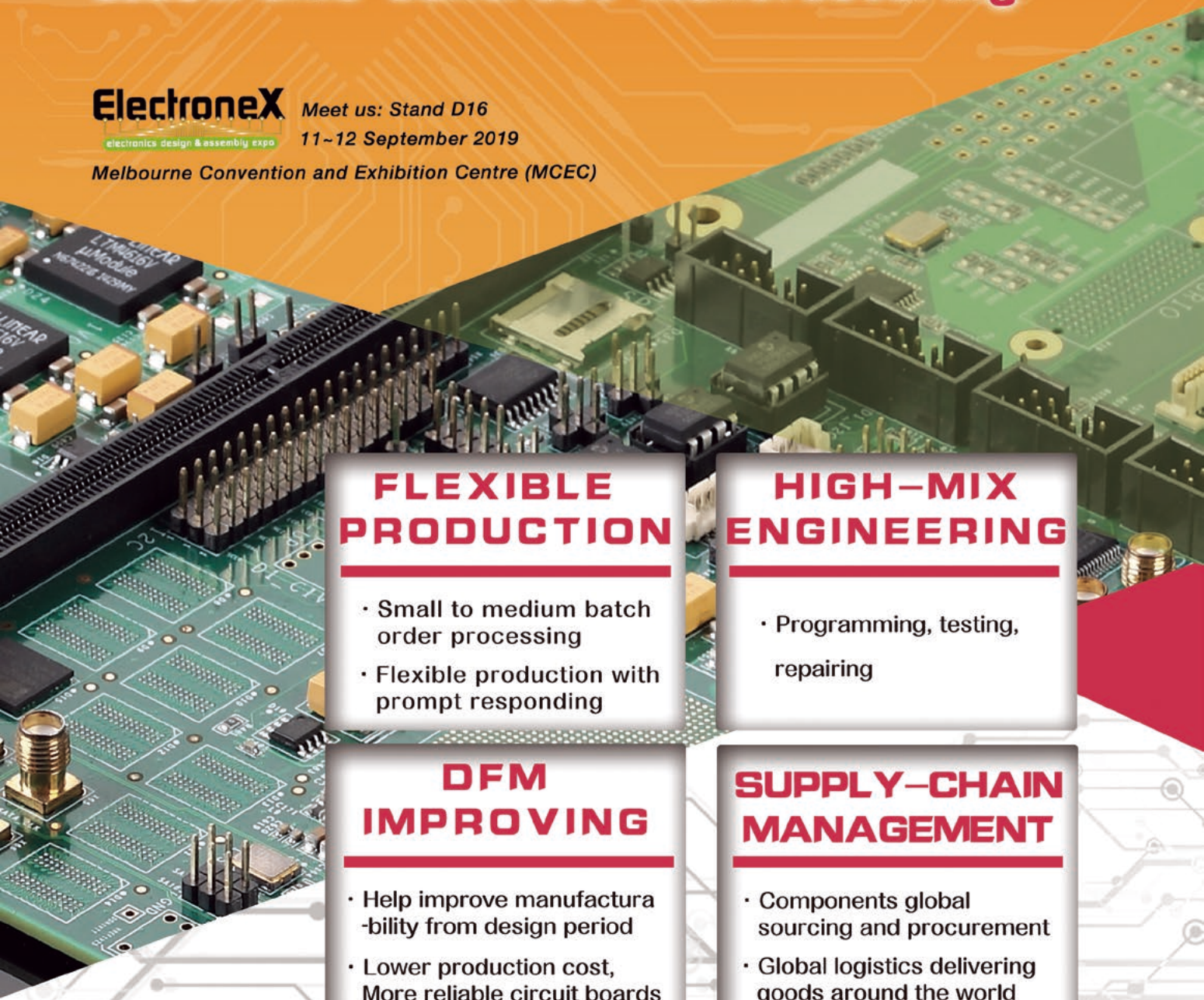

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terfering signal could be heard many kilometres from the repeater.

I started monitoring the repeater input frequency in my car as I went about my normal activities, to try to get an idea of where the signal was strongest. The interference could be heard all over the place with varying strength with no discernible pattern, although I had the impression that elevation could have been a factor.

I obtained a list of pager station locations and tried approaching several of these, however, the signal strength of the transmitters up close was so high that it swamped my receiver input and made it impossible to make any meaningful observations.

I solved that problem by connecting several spare cavities between my antenna and the receiver input, carefully tuned to the repeater frequency. I could now get right next to a pager station and maintain normal sensitivity of my receiver.

This approach eventually bore fruit as I was confident that I was hearing only the interfering signal, even when close to a pager station. One day, my travels took me further east than usual, and I began to receive much stronger signals than before as I moved towards the coast. Eventually, as I topped a rise to Bilgola Plateau, a flat area right near the coast, the interference came roaring in at S9+.

At first, I thought something had gone wrong with my gear, but it all checked out. Maybe I was seeing the actual interference! By inserting an attenuator into the receiver input and driving around a bit, I was able to establish that the signal was coming from a tower on the edge of a public park on the Plateau.

There was a hut next to the tower, and the door was open. People were working in there, so I approached them, introduced myself, explained what I was doing, and asked if they could tell me anything about the pagers. They said no, they did mobile phones, but they could give me a number for "the pager blokes".

I asked them if I could have a look at the pager gear. They showed me some very impressive rack-mounted transmitters with large heatsinks. Apparently, they were quite high-powered units. Connected to the transmitter outputs were, guess what, cavity resonators! These were not the home-brew, copper-pipe devices I was used to seeing, but were nicely finished commercial units.

I called the number the mobile phone guys had given me and spoke to a very helpful technical officer who listened patiently to my tale of woe. He said he would send a technician out to investigate the problem. When I suggested that the technician visit the repeater site to see the problem for himself, he agreed, and we arranged a time.

In due course, several members of the repeater committee met the Telstra technician, complete with his spectrum analyser, on site. After a coffee break to help our new friend recover from his long drive, we connected his spectrum analyser in line with the repeater and antenna via a T-piece, after assuring him that we had disabled the transmitter!

Monitoring the repeater's receiver audio while watching the spectrum analyser screen we could plainly see and hear the interference. Our new friend agreed that it was a pager signal, and that it probably was an intermodulation product of two networks. He said he would investigate the problem.

By the next morning, we were delighted to find that the interference had gone; but it returned at a lower level that afternoon.

Our friend phoned to explain what he had discovered. He had found a faulty cavity at the Bilgola site and having no spares at that time, had swapped it for a good one from the Parramatta site.

His thinking was that Parramatta would cause us less interference since it was shadowed from our repeater by the mountains to some degree. He had ordered a new cavity.

He was right, the interference level was lower, and by setting the repeater's squelch level higher, we were able to stop it from triggering the repeater. This was not ideal because it effectively reduced the sensitivity of the repeater, but at least we didn't have to listen to the repeater triggering constantly. It would do until the new cavity arrived.

I was curious as to why the pager units, which were transmit-only devices, should have cavities connected to them. Our friend explained that when several transmitters on similar frequencies are feeding antennas nearby, the transmitted signals from each antenna are induced into the adjacent antennas.

With no cavity resonators, there would be nothing to stop these induced signals being fed back into the power amplification (PA) stages of the other transmitters. These PA stages are highly non-linear (Class C), and when the transmitter is triggered, a whole spectrum of frequencies would be produced from the mixing of the transmitter output with the extra signals picked up by its antenna.

This whole mess would then be amplified and anything that could get through the PA stage's output circuit would be transmitted. These 'dirty' signals would be induced into the adjacent antennas as before, in turn generating a mind-boggling array of new modulation products.

The cavity on each transmitter prevents this by blocking the induced signals from reaching its transmitter and rejecting any spurious outputs from its transmitter.

A few weeks later, I received a call from our Telstra friend to say that he had installed the new cavity. I was able to report to him that there was now absolutely no interference, and to thank him profusely for his diligent attention to our problem. Full marks to Telstra and their staff!

Since then, a tone squelch system has been installed in the repeater. A sub-audible tone imposed on the user's audio is required to open the squelch, Preventing the repeater from being triggered by rogue signals. However, this does not prevent legitimate traffic from being subject to interference while the repeater is being used.

1970s Marantz 1120 amp repair

J. W., of Hillarys, WA did a mate a favour a few years ago and fixed a fault in his trusty Marantz amplifier. Now something else has gone wrong and so it's back on the workbench for some more surgery...

A few years ago, I repaired a friend's Marantz 1120 stereo amplifier (circa 1968). He rang last week to report another fault in the amplifier. I made a house call to check it out and found everything was working except for the phono input. There was no sound from the right channel. I disconnected the myriad cables from the unit and took the amp back to my workshop to check it out.

I connected the phono input to an iPod and wired up some speakers in my workshop and found the fault was still present – no output from the right

channel speaker. I dug around in my filing system and found the circuit diagram I used last time I fixed this amplifier, about six years ago.

The amplifier is built like a brick outhouse with 2mm steel plate used for the whole chassis and covers; not a bit of plastic in sight. I removed the nine screws holding the top cover in place and opened it up. I then identified the phono/select board assembly which sits vertically and plugs into another PCB behind the front panel.

I connected my CRO (cathode ray oscilloscope) to the two phono input channels and I could see both waveforms from my iPod. This was difficult as the vertical phono board has the input selector switch shaft running along the whole length. I then identified the output terminals from the phono preamplifier and connected up my CRO. The left channel was OK but nothing was coming out of the right section.

The circuit showed 6.8µF coupling capacitors connecting the output transistors to the selector switch, so I hooked up scope up to the driven side of the capacitors and found a good signal on both channels.

I then had to try to get the board free enough to replace the faulty capacitor; I did not want to remove it completely as this involved desoldering about 10 wires. After removing the aluminium front panel and another 10 screws, I was able to move the board enough to get to the capacitor.

Replacing the right channel coupling cap resulted in audio from both speakers. I decided to replace the left channel's coupling cap as well, to be on the safe side; after all, the amp is 50 years old! I wonder if a new amplifier purchased today would last that long.

My friend had also told me that the power-on indicator lamp was not working, so I checked that and found the globe (28V 40mA) was blown. I searched in my container of small globes and found a 6V 40 mA bulb that looked like it came out of a telecom switchboard or equipment rack.

The amplifier circuit showed a 390Ω 2W resistor in series with the globe, so after doing a bit of maths, I determined that a 1kΩ 1.6W resistor should allow me to use the 6V globe instead. I found a 1kΩ 3W wirewound resistor about the same physical size as the original and mounted it on the opposite side of the power PCB, to allow more air flow.

A bit of fiddling with the new globe had it mounted correctly and working. I left the amp running for a few hours and found no sign of the replacement resistor overheating. Since it was all working, I put it back together, took it to my friend's house and connected everything back up.

While I didn't ask for any payment, I was promised a bottle of scotch for my efforts; that's what you call a bonus!

Ducted vacuum repair

G. H., of Littlehampton, SA has had problems with two different vacuum systems and both of them involved Earth leakage faults. He managed to solve both...

Our house is about 20 years old. It has a weatherproof double power point on the back wall of the garage for garden appliances. About a year ago, plugging in and switching on the garden vacuum via the right-hand socket caused it to trip the Earth leakage detector in our main circuit board.

Oddly, after resetting the RCD, it worked fine. And I also found that using the left-hand socket never caused the RCD to trip. The fault ended up being a mass of spider webs embedded in the back of the power point. I cleaned it out thoroughly and sealed the gap in the wall around the power point, to keep spiders out.

We also have a ducted vacuum cleaner inside our house which has worked well for many years. The main unit is in the garage, so it produces very little noise and no smell of musk.

Then, a few months ago, as my wife pushed the cleaning hose into the wall socket, all the power to our house went off. The pipe has a metal ring which connects two terminals inside the wall socket, turning the unit on automatically. The switching is all done at low voltage for safety.

I unplugged the motor unit in the garage and checked the fuse box. The RCD had tripped again, presumably due to excessive Earth leakage. Resetting it restored power to the house.

I plugged the motor unit in and carefully switched on the power. The hose must have been left in the wall socket, so it sprang to life. We continued to use it without any problem until the other day, when the RCD tripped again. This time, I restored the power but left the motor unit unplugged.

I first measured the resistance from the low-voltage switching wires to Earth, Neutral and Active. I was pleased to see that all readings were open-circuit, so that part was safe. The low-voltage supply comes from a 12V transformer, which powers a relay to switch the Active conductor.

But the resistance between the Neutral and Earth pins of the vacuum motor was less than I expected. I measured the resistance between the Earth pin on the internal circuit board and both the Active and Neutral connections again; it was too low.

I disconnected the motor from the main board. Measuring the resistance from the motor power wires to the Earthed casing of the motor also gave low resistance readings.

So I began dismantling the motor carefully and measured as I proceeded. Eventually, I concluded that this leakage was due to carbon deposits which had come from the brushes. I thoroughly cleaned the carbon brush holders, then dried them before reassembly. All of the resistance readings were open circuit, as they should be, and since re-assembly, the vacuum has not missed a beat. SC

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Bridge-mode Audio Amplifier Adaptor

Let's say you want to put on a rock concert. You're going to need *thousands* of watts of power, and it's a bit impractical to stack up dozens of smaller amplifiers and speakers. What you need is something BIG.

You could build a few of our Majestic loudspeakers, described in the June and September 2014 issues (siliconchip.com.au/Series/275). You would build these using the alternative Celestion FTR15-4080FD woofer, giving you very sensitive speakers capable of being driven at levels of up to 1000W.

So that's the speakers sorted, but how to drive them?

The most potent audio amplifier we've published is a 500W job, in August-October 1997 (siliconchip.com.au/Series/146). As is typical for power amplifiers, it will produce its full rated power output into a 4Ω load. But the Majestic speakers have an 8Ω impedance, and so that amplifier module will only achieve a measly 278W into such a load.

That's just not good enough! The trick is to drive the speakers in bridge mode. If you build two of those amplifiers, plus this little device, you can drive a single Majestic speaker with two of these amplifiers.

And because the speaker's impedance is effectively halved when being driven in bridge mode, you will get that 500W figure from each. 500W + 500W = 1000W. Rock on!

The way it works is simple. This Bridge Adaptor (often called a BTL [bridge-tied load] adaptor) splits your audio signal in two. One output signal is virtually identical to the input, while the other is inverted.

So when you connect those outputs to two audio amplifiers (possibly the

BY NICHOLAS VINEN

two channels within a single stereo amplifier), the outputs swing in opposite directions.

That means the voltage between the outputs is double that of a single output. This arrangement is shown in Fig.1.

Since the power into a load can be calculated as $V^2 \div R$, if you double the voltage but keep the impedance constant, you quadruple the power.

Of course, this is assuming your amplifier is capable of delivering that much power. But if you use an 8Ω speaker, since most amplifiers will happily drive a 4Ω load, it should be capable of it.

You do have to be careful if using a 6Ω or 4Ω speaker since many amplifiers will not be very happy with a 3Ω or 2Ω effective load.

Performance

We ran our prototype through a number of tests using our Audio Precision System Two. We haven't reproduced any of the resulting graphs here since the results can be summarised in just a couple of paragraphs. We used a 15V AC plugpack as the power source during these tests.

The distortion and noise levels are very low. The signal-to-noise ratio is 114dB with respect to 2V RMS (a common signal level from a CD/DVD/Blu-ray player), with a measurement bandwidth of 20Hz-22kHz. The frequency response is ruler-flat, being only 0.2dB down at 20Hz and less than 0.1dB down at 20kHz.

THD+N is 0.0005% from the non-inverting output and 0.0006% from the inverting output over the 20Hz-20kHz range with an 80kHz bandwidth.

Measuring with a 20kHz bandwidth, these figures reduce to 0.0003% and 0.0005% respectively. The distortion across the two outputs (ie, what you would actually hear) measures the same as the inverting output.

Updated version

We published a Bridge Adaptor in the July 2008 issue. This one is considerably smaller and will fit into a UB5 Jiffy box for convenience. But you also have the option of building it into an amplifier chassis if that's what you want.

This design also has much more flexible power supply options. It will run off AC, DC or split rails. It also uses parts that are easier to get, and cheaper, than our last design.

The circuit diagram is shown in Fig.2. The input audio signal is fed in via RCA socket CON1, which has a 100kΩ resistor to bias the input signal to 0V (if it's floating). That signal then passes through two "back-to-back" electrolytic capacitors.

We've used this arrangement, rather than a single non-polarised (NP) electrolytic capacitor because the size and cost of NP capacitors can vary dramatically. By using two small, low-cost regular electrolytics, we get the same effect with a low price and small footprint.

The signal is DC-biased to signal ground (more on that later) with a 10kΩ resistor, and RF signals are filtered out by a 100pF ceramic capacitor. The signal is then applied to the non-inverting input, pin 3, of low-noise op amp IC1a.

IC1a acts as a buffer, feeding both non-inverted RCA output connector CON2, and the inverting stage, which is based around op amp IC1b. The signal to CON2 passes through another pair of 22µF DC-blocking capacitors and is re-biased to 0V DC via a 100kΩ resistor.

The 100Ω series resistor protects IC1a against an output short circuit and also isolates any cable capacitance to prevent oscillation.

IC1b is configured as a classic inverter with a gain of -1, set by the ratio of the two 2kΩ resistors. These values were chosen to keep noise to a minimum without unduly loading the output of IC1b.

After all, it has to drive whatever is connected to inverting RCA output connector CON3 as well. The signal is coupled from IC1b to CON3 in the same manner as described for CON2 above.

IC1b's non-inverting input, pin 5, is tied to signal ground

Features & specifications

- Up to four times the power into a single speaker, using a stereo amplifier or two mono amplifiers
- Low noise and distortion
- Powered from 9-16V AC, 12-40V DC, 18-32V centre-tapped transformer or ±6-20V DC (split rails)
- Low current draw – around 10mA
- Fits inside a compact, low-cost UB5 Jiffy box
- Can also be mounted inside an amplifier chassis
- A switch can be used to change amp mode between stereo and bridged mono
- Uses low-cost, commonly available parts
- Suitable project for beginners

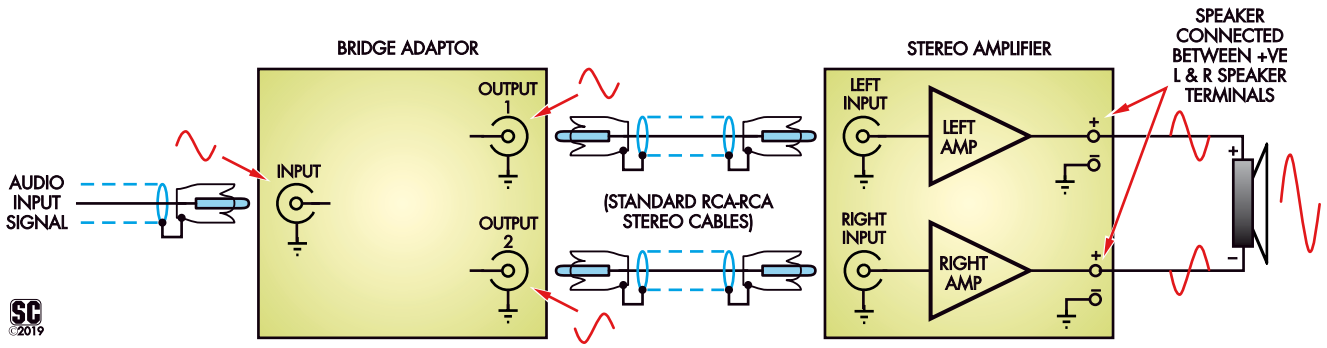


Fig.1: the Bridge Adaptor is connected to two power amplifiers (separate mono amps, or two channels in a stereo or multi-channel amp) to drive a single loudspeaker. This doubles the maximum voltage across the speaker, and increases the output power to up to four times the original. Only the active terminals of the amplifiers are connected to the loudspeaker while the ground terminals are not connected. Note that this will not work with an amplifier that's already internally bridged, ie, where both the positive and negative outputs are actively driven!

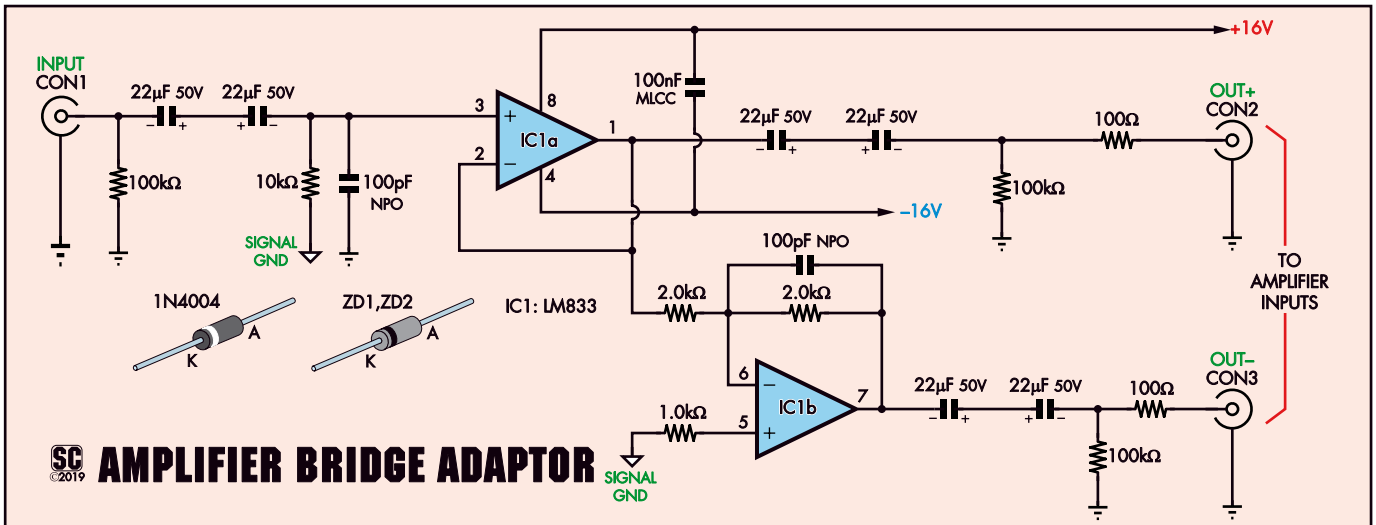


Fig.2: the circuit of the Bridge Adaptor, (also known as a BTL, or bridge-tied load adaptor) without the power supply (shown in Figs.3&4) . The incoming audio signal is AC-coupled to non-inverting input pin 3 of IC1a, which acts as a buffer. The buffered signal is fed to CON2 and also IC1b, which inverts the signal and then feeds this inverted version to CON3. By connecting CON2 and CON3 to two separate single-ended power amplifiers (or left and right channels in a stereo amplifier), you can almost quadruple the power delivered to a single speaker.

via a 1kΩ resistor. This means both of its inputs (pins 5 & 6) have the same source impedance, as the two 2kΩ resistors are effectively in parallel, given that both are driven from op amp outputs, which have an effective impedance close to 0Ω.

Power supply options

You can power the Bridge Adaptor from a 9-16V transformer, standalone or plugpack, or you can use a 12-40V DC supply, a ±6-20V DC split supply, or an 18-32V centre-tapped transformer.

That last option is most useful if you're building this project into an amplifier chassis. Later on, we'll show you how to wire up a switch so that an amplifier can be easily configured as either stereo or bridged mono.

When the unit is powered from AC or a split rail DC supply, signal ground is tied to power supply ground by a 0Wresistor (ie, wire link), as shown in Fig.3.

But if the unit is powered from a single DC supply (eg, 12V DC) then signal ground needs to be around 6V DC, so that the AC signals have a symmetrical swing.

The power supply section is therefore reconfigured, as shown in Fig.4, by omitting some components and replacing others with wire links.

In this case, the 0Ω resistor is instead 10kΩ, and another 10kΩ resistor forms a voltage divider across the DC supply rail, to generate a half-supply rail for signal ground. A 220µF capacitor between signal ground and power supply ground prevents any ripple or noise on the supply rail from getting into the signal ground, and thus affecting the audio signal.

It also presents a low AC impedance to the op amp feedback divider, so that the unit's frequency response is not affected by the resistors used to generate the signal ground rail.

Before construction

Before you start assembling the board, if you're going to be fitting it in a UB5 Jiffy box, place the board in the bottom of the box and use a marker to place dots in each location where a mounting hole is required.

We've provided four different PCB overlay diagrams, to show what components you need for each supply configuration.

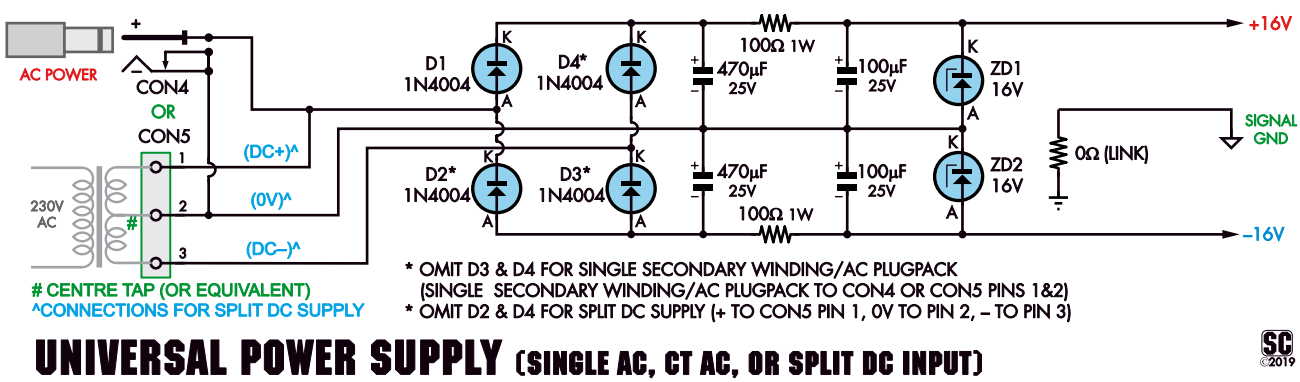
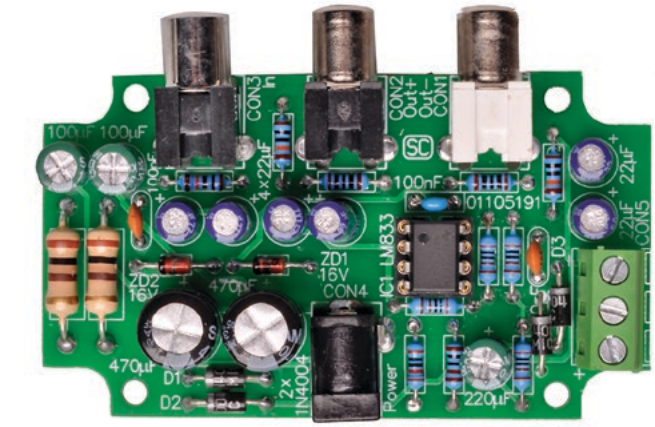


Fig.3: this shows a "universal" power supply, suitable for a single ended DC input, a split DC input (ie, +V/0V/–V) *or* an AC transformer with or without a centre tap. CON4 is used for single-ended DC or AC since it only has two contacts. CON5 is used for split DC or an AC transformer with centre tap.



This photo of the PCB actually has ALL the power supply components shown in the four overlays. Some are obviously not necessary, depending on the version you build. (Use the component overlay for your version).

Fig.5 shows the components required for a transformer with a single secondary (including most AC plugpacks) and Fig.6 for a transformer with two secondaries connected in series, or a single centre-tapped secondary.

Fig.6 also applies if you have a transformer with individual secondaries (eg, two 9V or two 12V secondaries). In this case, the phases of the windings need to be correct: the end of one secondary is connected to the start of the other secondary to effectively form a centre-tapped winding.

You need to be careful with this connection – measure across the two windings (ignoring the centre tap) to ensure you have twice the individual winding voltage.

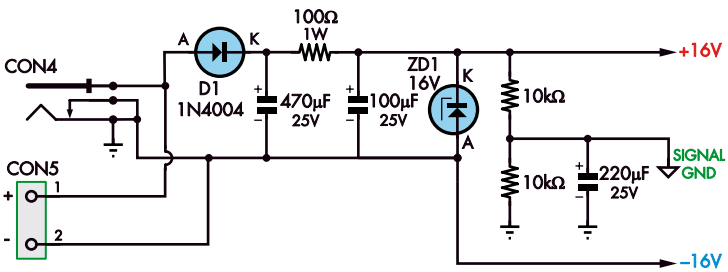
If you get 0V (or close to it) you have connected the two windings incorrectly.

Where a split DC supply is called for (eg, +15-0-15V) use the overlay shown in Fig.7, whereas a single DC supply uses the overlay shown in Fig.8

So let's get building!

Start by fitting the smaller resistors. While these have colour-coded bands indicating their values (as shown in the parts list), because certain colours can look similar depending on your lighting, it's much safer to measure their values with a multimeter before installing them. Use the appropriate overlay diagram as a guide as to which resistors go where.

Next, fit whichever of diodes D1-D4 are required for your particular configuration, followed by zener diodes ZD1 and (if needed) ZD2. In each case, ensure that the cathode stripe



POWER SUPPLY (SINGLE-ENDED DC)

Fig.4: the power supply can be much simpler when the unit is only to be operated from a single-ended DC supply. Some components are omitted while others have their values changed. The negative supply rail for dual op amp IC1 is connected to 0V via a wire link, while the signal ground is biased to half supply by a pair of resistors and a capacitor.

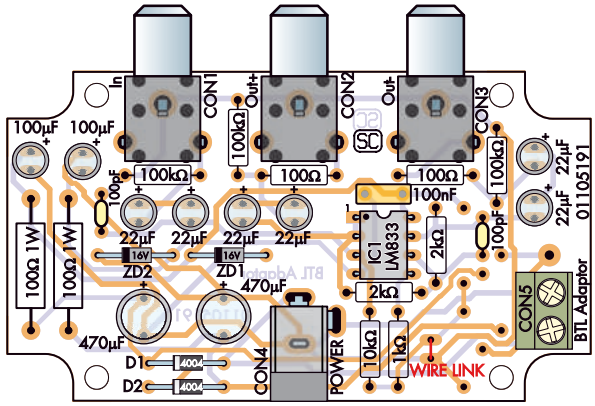


Fig.5: here's the overlay for a single AC supply, from either a 9-16V transformer or plugpack, plugged in to CON5.

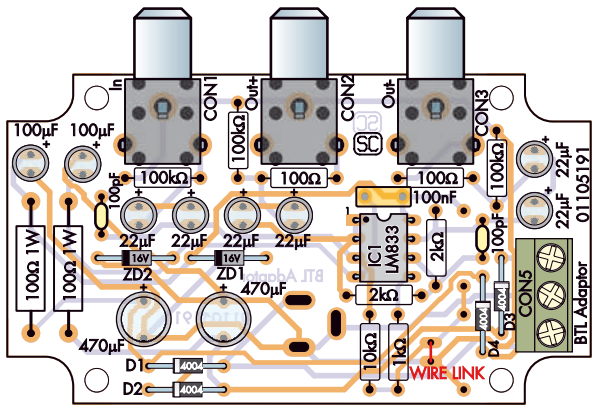


Fig.6: if you have a transformer with a centre-tapped secondary, use this overlay.

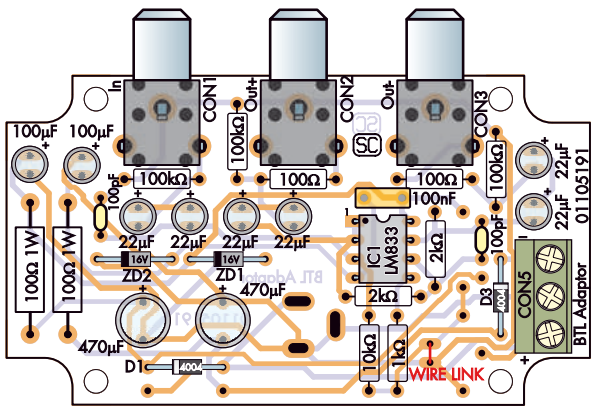


Fig.7 if you have a split DC supply (eg, ±15V & 0V) you will connect it to CON5 and omit some components.

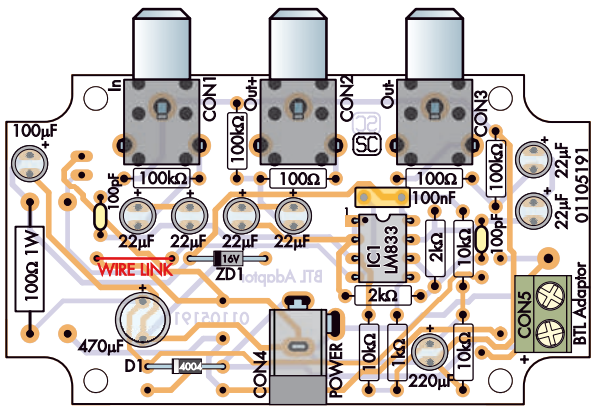


Fig.8: this overlay is for the single-ended DC supply, as shown in the circuit diagram at left.

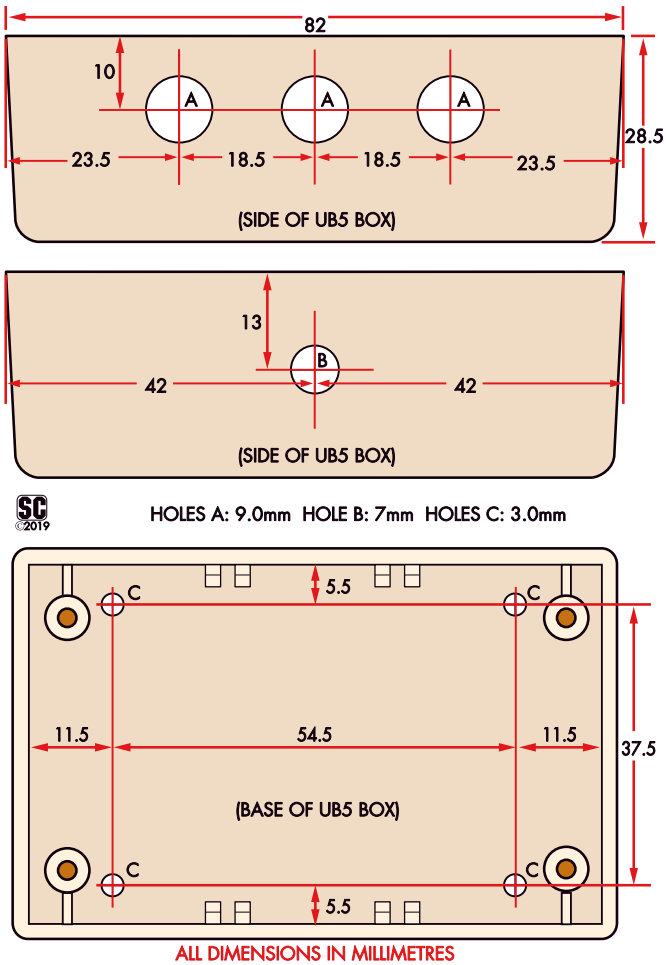


Fig.9: if you're mounting it in a UB5 Jiffy box, here's where to drill the holes required in the sides and base. The PCB is attached to the base using untapped spacers and machine screws (see parts list & text).

faces in the direction shown on the overlay diagrams, ie, towards the top or left edge of the board.

Now install the 1W resistor(s) and a socket for IC1, assuming you're using one. You can then mount the two 100pF capacitors and single 100nF capacitor. None of these are polarised.

Follow with the terminal block, if you're going to be using it, ensuring that it is pushed down flat onto the board and that its wire entry holes face the nearest edge.

You can use a 3-way terminal block for all four configurations, however, with two of the configurations, only a 2-way block is required as shown in Figs.5 & 8.

If using a two-way block, make sure to solder it to the right pair of pads.

Now fit the electrolytic capacitors. These are polarised and must be orientated correctly. The longer (+) wires go into the pads marked with a "+" on the PCB, towards the top edge of the board. The striped side of the can shows the negative terminal, so the stripes should all face towards the bottom edge.

There are three different types of electrolytic capacitors used, so don't get them mixed up.

Finally, fit the RCA terminals and DC socket (if required). In each case, make sure the connector is pushed down fully onto the PCB and lined up nicely with the PCB edge before soldering its pins. Be generous with the solder as these pins are quite large.

Testing

Before mounting it, it's a good idea to test the unit. If you've fitted a socket for IC1, you can leave IC1 out until you have verified that the power supply is working OK.

It's best to test the unit with the same type of supply that you will eventually be using, however, if you intend to use a centre-tapped transformer or split supply, you could use a 9-16V AC plugpack for initial testing.

Apply power and measure the voltage between GND (eg, the RCA connector shells) and pin 8 of IC1 (or its socket). If using an AC supply, you should get a reading of around +16V DC, or perhaps slightly lower if your AC supply is below 12V. Similarly, pin 4 of IC1 should be at around -16V DC. Pin 5 should be close to 0V.

If you're using a DC split supply, you should measure voltages at pins 8 & 4 of IC1 that are around 0.7V less than the applied voltages, while pin 5 should be close to 0V. And if using a single-ended DC supply, pin 8 should be around 0.7V less than your applied DC voltage, while pin 4 should read 0V and pin 5 should be almost exactly half the reading at pin 8.

If you get readings that are significantly different from those described above, switch off power and check your board carefully. Things to look out for are bad solder joints, incorrectly orientated components or components that are in the wrong location.

If the power supply checks out, switch off power, short out pins 4 & 8 of IC1's socket briefly (to discharge the capacitors) and then insert IC1 in its socket. Re-apply power and apply a signal to CON1, from a Blu-ray player, iPod, mobile phone, PC or whatever's convenient. Connect CON2 to the input of an amplifier with its volume set to minimum, then slowly ramp its volume up.

You should hear the input signal being reproduced cleanly. Disconnect CON2 from the amplifier and connect CON3 instead. You should again hear the input signal being reproduced cleanly (the fact that its phase is inverted will not be audible).

You can now do a final test, with CON2 hooked up to one amplifier input and CON3 to another, and the speakers connected across the amplifier outputs, as shown in Fig.1. Again, you should hear the signal loud and clear. Only

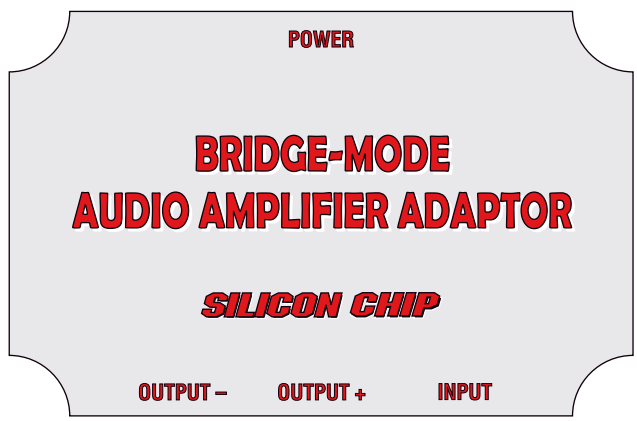


Fig.10: same-size label which fits the UB5 Jiffy box. You can photocopy this or download it from siliconchip.com.au/shop/11/4972

this time, the maximum output power of the combined amplifiers will be much higher!

Mounting it in a box

As mentioned above, you will need to drill four 3mm holes in the base of the Jiffy box. If you forgot to do that earlier (using the PCB as a template) you could instead make the holes where shown in the drilling diagram, Fig.9.

You will also need to drill three 9mm holes in one side of the box for the RCA sockets, plus a 7mm diameter hole in the opposite side to access the barrel socket. The positions of these holes are also shown in Fig.9. You can copy this diagram, cut out and stick the copy onto the box and then mark and drill the holes.

Ensure the template is aligned accurately with the top, bottom and sides and drill the holes accurately, starting with a smaller pilot drill and then enlarging to side with larger drill bits, a stepped drill or a tapered reamer.

This ensures that the unit will fit nicely in the box and look neat.

Once you've made the holes, deburred them and removed any debris from the box, feed the four 16mm

Parts list – Bridge-mode Adaptor for Amplifiers

1 double-sided PCB, code 01105191, 79 x 44.5mm
1 UB5 Jiffy box (optional)
3 PCB-mount right-angle switched RCA sockets (CON1-CON3)
1 PCB-mount right-angle barrel power socket (CON4) ***AND/OR***
1 3-way (or 2-way) mini terminal block (CON5)
1 8-pin DIL IC socket (for IC1)
4 3mm inner diameter, 6.3mm long untapped spacers
4 M3 x 16mm machine screws
4 M3 hex nuts

All of these components are commonly available from your normal parts suppliers. The PCB (01105191) is available from the Silicon Chip Online Shop.

Semiconductors
1 LM833 or NE5532 dual low-noise op amp (IC1)
2 16V 1W zener diodes (ZD1,ZD2)*
4 1N4004 1A diodes (D1-D4)★

★ *only two needed for single AC/split DC supply*
* *only one required for single-ended DC supply*
^ *only required for single-ended DC supply*

Capacitors
2 470µF 25V electrolytic*
1 220µF 10V electrolytic^
2 100µF 25V electrolytic*
6 22µF 50V electrolytic
1 100nF 50V multi-layer ceramic or MKT *(code 100n, 104 or 0.1)*
2 100pF 50V NP0 ceramic *(code 100p or 100)*

Resistors (all 0.25W, 1% metal film unless otherwise stated)
3 100kΩ *(brown black yellow brown or brown black black orange brown)*
3 10kΩ *(brown black orange brown or brown black black red brown)*
2 2kΩ *(red black red brown or red black black brown brown)*
1 1kΩ *(brown black red brown or brown black black brown brown)*
2 100Ω *(brown black brown brown or brown black black black brown)*
2 100Ω 1W 5%* *(brown black brown brown or brown black black black brown)*

In one word . . .

Majestic!

You will go a long, long way to find speakers with anywhere near the performance of the Silicon Chip *Majestics* – certainly in the do-it-yourself world, and even compared to ready-built models.

Detailed, blind listening tests confirm they are at least as good as – and some say better than – speakers costing ten times as much!

At 486(w) x 864(h) x 580(d)mm each, you will certainly reuire plenty of room for the *Majestics*. They are most suitable for large listening areas, especially where you want high levels of crystal-clear sound. How high? Spectacularly high!

They feature an etone or Celestion 15-inch woofer, teamed perfectly with a Celestion T5134 diecast horn tweeter and matching compression driver, plus a two-way first order crossover.

Building the *Majestics* is well within the capabilities of the average constructor. They're not cheap – they certainly won't leave any change out of $1000 per pair (and probably a bit more!). But if you want exceptional power and performance, you can't go past the *Majestics*.

For more information, see a preview of the *Majestics* articles at siliconchip.com.au/Article/7897 & 7997

Here's what it looks like mounted in the UB5 Jiffy box (sans lid!), drilled as shown in Fig.9. If CON5 is used, access holes would also be needed on that side.

And here is the finished device, complete with a panel (see text). The beauty of this design is that no extra holes are required in the panel itself – they're all in the box sides.

machine screws up through the bottom of the box and set it on a flat surface so they won't fall out. Next, drop the 6-7mm untapped spacers over the screw shafts and lower the board into the case.

To do this, first insert the RCA socket barrels through the holes in the case, then drop the opposite edge down into the box. You may have to push a little, getting the box to flex, to get it into place. Once all four screw shafts are through the holes on the board, use thin-nosed pliers to hold a nut on top and do up each screw one at a time.

This is a bit tricky since initially, the other three screws will be loose, so you can't just lift up the box, or they will fall out.

We did it by sliding one corner of the box over the edge of the desk while holding that screw so it couldn't fall out, then carefully rotating it so it threaded onto the nut, then moving on to another corner. Each nut you thread will make it easier to do the next one.

Alternatively, you could use Blu-tack, silicone sealant or some other type of glue to temporarily hold the untapped spacers over the holes in the box while you insert and do up the screws.

Do them all up tight, then put the lid on the box and affix the label. The artwork for the label can be downloaded from the SILICON CHIP website in PDF format and then printed out.

For information on how to make a label, see: **www.siliconchip.com.au/Help/FrontPanels**

Mounting it in an amplifier

If you want to integrate it into an amplifier, this is quite easy. You can use longer tapped Nylon spacers and mount it to the bottom of the chassis using eight short M3 machine screws.

It's then just a matter of wiring up the AC or DC power supply connections to CON5 and connecting the audio signals using cables terminated with RCA plugs.

You could make these by simply buying two RCA-to-RCA plug cables and then cutting them in half and stripping off the insulation.

Fig.11 shows how you can use a standard SPDT switch (toggle, latching pushbutton, rotary or slide) to allow the amplifier to be reconfigured as either stereo or bridged mono at any time.

Using it

If you've built the unit into an amplifier with the switch as described above, you can apply a stereo signal to the amplifier's left and right input channels, with the switch in the STEREO position, and it will operate normally as a stereo amplifier.

Or apply a single signal to the left input channel and put the switch in the MONO position, then connect a speaker wired as in Fig.7 for the bridged mono mode.

Or if you've built the unit into a Jiffy box, connect it to a stereo amplifier or pair of mono amplifiers as shown in Fig.1, for mono mode.

If you want to use the stereo amplifier in stereo mode, merely disconnect the unit and wire up the inputs and speakers as you usually would. SC

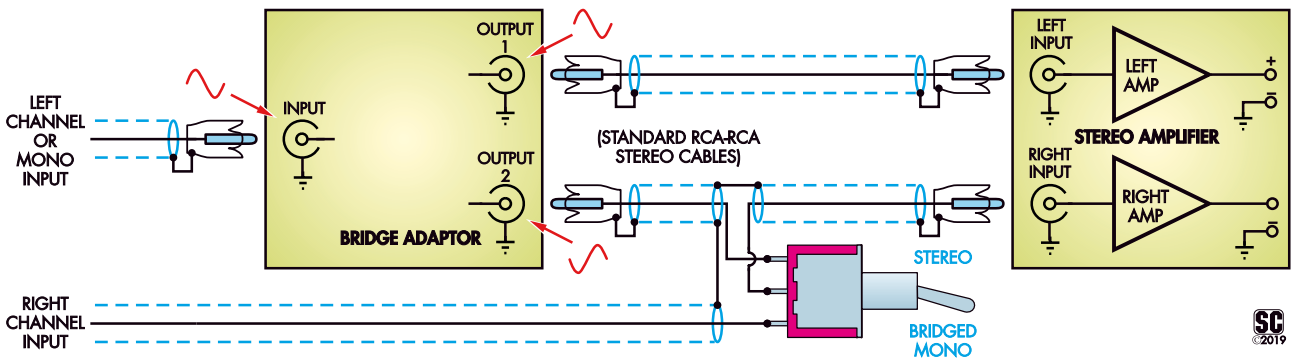


Fig.11: this is how you can use an SPDT switch to allow an amplifier to be easily reconfigured as either stereo or bridged mono. This makes a lot of sense when building the unit into an amplifier; when building it separately into a box, you can easily achieve the same result by re-plugging cables. The switch is shown here as a toggle type, but it could be a push-on/push-off, slide or even rotary switched.

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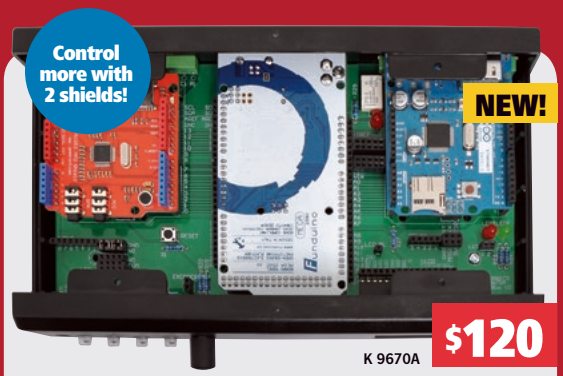

K 9670A **$120**

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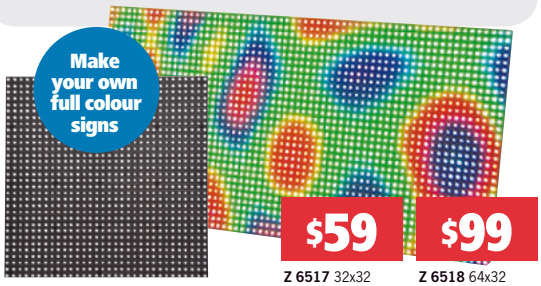

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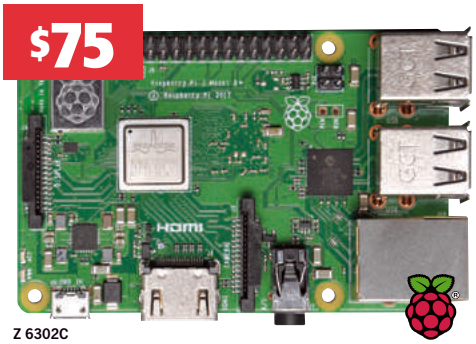

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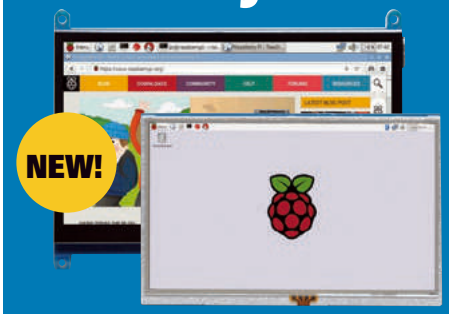

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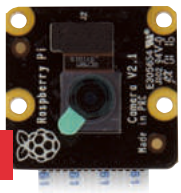

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NEW!

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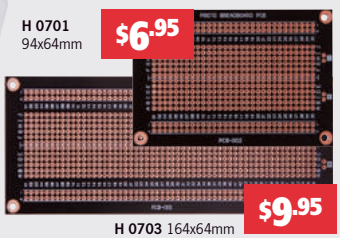

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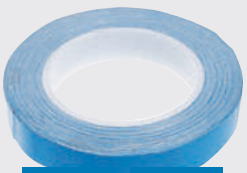
4xAA IP68	SW5046	$9.95

NEW!

Solder Splice Joiners

By popular demand! Heat up and join cables together without the need for manual soldering. Melts at 450°C. Packs of 6.

Size	Model	ONLY
White 26-24AWG Pk6	W 0800	$4.25
Red 22-18AWG Pk6	W 0804	$4.50
Blue 16-14AWG Pk6	W 0808	$4.75
Yellow 12-10AWG Pk6	W 0812	$4.95



SAVE 25%
$19
T 2969 20mm

SAVE 25%
$10
T 2967 10mm

Thermal Transfer Tape

Protects your batteries & terminals from the elements. Screw together. 140mm fly lead.

Upgrade & Save on Digital Multimeters

All-Rounder Student DMM

The perfect beginner, student or enthusiast multimeter. 12 auto ranging test modes with good accuracy and an easy to read jumbo digit 4000 count screen. Includes test leads.

Q 1129

19 Range Pocket Multimeter

A mini 3.5 digit digital multimeter with 19 ranges. Small enough to literally fit in a pocket, this multimeter Includes K-Type temperature probe, data hold function and switchable backlit display.

Q 1126

20 Range True RMS Meter

An affordable true RMS digital multimeter for the technician. True RMS offers increased accuracy when measuring AC voltages. Also includes a frequency counter, capacitance range, data hold and an easy read backlit LCD. **Q 1070**

Autoranging True RMS Multimeter

A high accuracy model for those requiring true RMS ac waveform measurement. Huge feature list - check online for more info. Relative function, backlit LCD, USB datalogging. Cat III 600V.

Q 1074A

Do-It-All Multimeter

With in-built AC mains detection. This is one of the best DMMs we have evaluated when it comes to build quality and feature set. Its perfect for the serious enthusiast or tradesperson • 3.75 digit display • LCD bargraph • Mode assistance indicators. • Includes carry case, temp probe & insulated test leads. **Q 1068**

Super-Tough DMM. Built like a tank!

This new multimeter is built tough with water and dust resistance, plus a impact resistant case for the rough and tumble of every day use in the field. Auto ranging design offers a feature list as long as your arm with a clear large digit backlit display. Includes carry case & test leads. See web for full spec list. **Q 1069**

Q 0102 **$349**

Powerful diagnosis tools in the palm of your hand.

All the power of a benchtop oscilloscope in the palm of your hand. This compact digital storage oscilloscope and digital multimeter makes field testing easy, even when working in tight spaces or with equipment on site. Offers 2 channels with real time sampling of 125MSa/s per channel with waveform comparison tools and a full range of accessories (plus carry case).

Q 2022 **$64** SAVE 19%

'Roadies' Cable Tester

Tests 13 types of leads for continuity. A real time saver! Tests: 6.35mm, DIN (3/5/7/8 pin), RCA, XLR (3/5 pin), Speakon (4P/8P), RJ45, USB & banana. Requires 9V battery (S 4970B $3.95).

Q 3003 **$29** SAVE 27%

Detect lethal AC voltages instantly.

This non-contact probe detects cabling and power outlets with live AC power. An essential safety tool for trades people. Waterproof case with in-built torch.

Q 1344 **$130** SAVE $45

Network & Coaxial Cable Verifier

Tests both cable length and integrity in both RJ45 UTP data and BNC coaxial cabling. It's wiremap system detects short circuits, split pairs and cable lengths up to 350m. Powered by USB rechargeable internal battery.

M 8303 3A **$109** M 8305 5A **$139**

Compact 30V Lab Power Supplies

Great for servicing, repair and design of electronics. Low noise switchmode design. Fine & coarse voltage and current controls. Size: 85Wx160Hx205Dmm.

Q 1278A **$19.95**

Handy Probe Thermometer

Stainless steel easy clean probe. Great for use in the lab/kitchen. -50°C to +330°C. Includes battery.

SAVE 35% **$12** X 0209A

Tough Aluminium LED Torch

With adjustable 3 Watt beam! ≈120mm long. Requires 3xAAA batteries. Includes pouch.

Q 1127 SAVE 22% **$10**

Temperature Probe for DMM

-20 to 1320°C. Banana plug

D 3002 **$29.95**

Simple PoE Port Tester

Checks status of data and power over ethernet connection. Includes lead for testing socket points.

SAVE 36% P 0415 **2 For $14**

Crocodile Clip Test Leads

Packs of 10. Red, black, green, white, yellow (2 of each). 275mm length.

SAVE 30% **$35** T 2261

Mini Pocket Scales

Weigh anything up to 600gm with 0.01g precision. Includes case.

Stay Powered Up Anywhere.

120W Folding Solar Panel With Regulator

Going bush? Have power wherever you go on your next 4WD adventure.

• Includes 120W panel, solar regulator, battery connection cables and canvas carry case. • 3 stage solar charger ensures your batteries are performing at their peak! • Adjustable stand for easy orientation. • 720x520x70mm (folded).

Laptop & USB Car Charger

Simply plugs into a car accessory socket. Up to 90W power output. Includes 9 laptop adaptors - see web for compatibility list.

Price Breakthrough! 20A Solar Charger

High current solar chargers were once sold for over $200 - these new quality units are less than $100 and feature USB charging and a full LCD readout with essential battery information. Suits 12/24V systems.

Protect Your Battery With ANBI® Switch

ANBI is an isolator which prevents your battery from draining when not in use by isolating the negative terminal. Also a great anti-theft device! Ideal for cars, boats, caravans, even mowers! Installs in a few minutes.

Need an extra laptop charger for work?

This powerful 45W USB-C power delivery (PD) charger offers fast recharging for the latest MacBooks, Nintendo Switch, notebooks and other type "C" equipped devices. Also provides two standard type "A" USB outputs.

Phone Holder with Wireless Charging

Simply place your phone in the holder to keep it topped up whilst you're driving! Convenient windscreen or air vent mounting. Great for Uber drivers or road reps.

Replacement Laptop Supply

Lost your laptop power supply? Or need an extra one for the office? This unit includes mains lead and 10 tips to suit popular models of laptop. Voltage output is set automatically. 5-24V @ 90W max.

Easy Read Volt & Ammeter

Simultaneous display of voltage & current. Plus power, charging capacity & time measurements. Ideal for battery monitoring. 79x43x25mm. 20A max.

USB C Type QC3.0 In-Car Charger

Need to keep your laptop charged up in the car? No problem! This powerful C type charger provides QC3.0 charging capability up to 18W output.

Panel Mount Volt/ Ammeter

Reads 6-30V DC voltages up to 10A current. Internal shunt. Suits P 0679/80/81 facia plates. 28mmØ mounting hole.

4 Way Quick Charge 3.0 USB Charger

'Charge IQ' feature charges a connected device at the fastest speed. 4A max current. 110-240V - great for travel. Includes mains lead. 62W x 97D x 31Hmm.

Lithium-Ion Car Jump Starter

Suits 12V battery vehicles. 20000mAh rated battery provides up to 1000A peak output when cranking. Two USB ports are provided for charging devices (like a giant battery bank!). It also has a super bright 1W LED torch in built. • 178L x 84W x 45Dmm.

USB NiMH/NiCad Charger

Charges 4 x AAA/AA cells via USB. Great for use at home or in the car. Use rechargeables & save batteries from landfill!

Dual 12V Battery Isolator Kit

Provides everything you need to wire up a secondary battery in your vehicle - vital for powering appliances at campsites, inverters etc, and isolating the primary battery so you have enough juice to start your car! Instructions included.

Mains Power Anywhere, Anytime!

Great for camping, farmers, mobile trades, service vans. • Host of protection features • Soft start • High/low voltage shutdown

Rating	Model	Normally	ONLY
12V 150W	M 8072	$59.95	$44
12V 300W	M 8076A	$79.95	$58
12V 600W	M 8084	$129	$95
12V 1000W	M 8090	$235	$175

Inflate a tyre. Start a flat battery.

Great for the 4WD or car enthusiast. Features a 16800mAh battery bank plus emergency compressor to top up tyres (max 8 mins run time). Provides 600A peak battery cranking output. 12/16/19V & USB output provided for powering devices.

Build the ultimate electronics workbench!

Top buy for the beginner or student.

T 2090

$59.95

Bargain 40W Soldering Station

Top value for money and features for beginners or cash strapped students/enthusiasts. Lightweight non-slip handle with tip cleaning sponge and iron safety holder. Full range of spare tips also available.

$175

T 2065

SAVE $40

Micron® Vacuum Desoldering Station

Designed to desolder through hole componentry, removing molten solder quickly and easily from solder pads and components. In-handle reservoir is easily removed and cleaned. Includes three desoldering tip, nozzle cleaner and filter pads. 160°-480°C.

Features 3 preset channels for quick temp selection.

$269

SAVE $66

T 2460A

Touchscreen Control Soldering Station

A sturdy 100W benchtop soldering station featuring an all aluminium case and 2.8" touchscreen for quick temperature and preset selection. 100-500°C temp range with slimline handle featuring burn resistant cable.

Great for cleaning Mum's jewellery!

$119

SAVE $40

Clean & Revive Small Parts

This 80W ultrasonic cleaner uses water and household detergent, coupled with ultrasonic waves to clean jewellery, small parts, DVDs etc, without damage - no solvents required. Stainless steel 18x8x6cm tank. **X 0109**

Cut, Polish, Grind, Sand & Carve!

SAVE $14.95

This workbench essential is just the shot for electronics projects, crafts, hobbies and odd jobs around the house! Powerful 130W motor with variable speed between 8000 and 33000 RPM. Included is a 172pc accessory kit of grinding wheels, drills, cutters, sanding discs, polishing pads and more! Stows away in a hard plastic carry case. **T 2120**

$60

$99

NEW!

T 1297

Swing Arm Benchtop Fume Extractor

Whisk away irritating solder fumes instantly as you work. The replaceable active carbon filter absorbs fumes for a cleaner work environment. Includes 100mm ducting adaptor. Easily screw clamps to your work bench.

USB Clip On 5x Magnifier Lamp

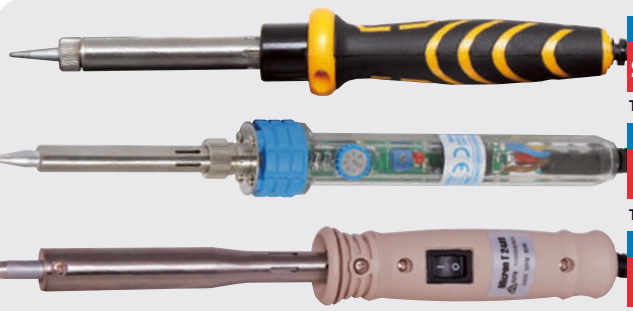
The latest Inspect-A-Gadget magnifier is powered by a USB port and provides a crisp, clear view of your workbench. 430mm long. 1.5m USB lead.

Clips to any desk or bench in an instant!

SAVE 30%

$27.95

X 0435



NEW!

$19.95

T 2440 60W

SAVE 19%

$28

T 2487A 50W

SAVE 25%

$18

T 2483 80W

Micron® Handheld Soldering Irons

An iron for every occasion! T 2440 is ideal for general purpose soldering. T 2487A features adjustable temperature for more sensitive work. T 2483 is a heavy duty chisel tipped iron for tinning large cable, terminals and joins.

Lockable Tool Field Case

With tool pocket & perforated foam inner to keep equipment secure. Ext. size: 445x330x128mm.

SAVE 30%

$55

T 5021

SAVE $20

$39

T 2152

Zip Up Precision Tool Set

A combination of spring loaded pliers/cutters & ferrule top screwdrivers in a folding carry case. Perfect for field servicing.

NEW!

$69.95

T 2175A

1000V Rated Insulated Tool Kit

Ideal for technicians working on mains powered equipment. Includes cutters, pliers, wire strippers, 5 screwdrivers plus a neon test driver and 2 rolls of insulation tape - all in a handy carry case.

Shaft extends 50mm

T 2189A

SAVE 44%

$15

14pc Mini Ratchet Driver

All in one design with bits stored in the handle. Great for the desk drawer for when you need to do odd jobs.

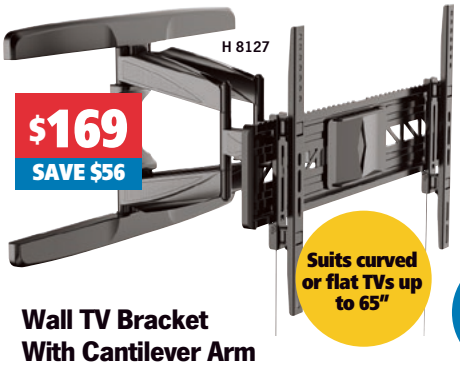
SAVE 27%

$29

T 2186A

101 Pc Ratchet Driver Kit

A tool for every occasion! Features 95 security, philips, pozi and slotted bits made from tough S2 alloy. Includes two way ratchet handle with comfy rubber grip. See web for full contents list.



H 8127

$169
SAVE $56

Suits curved or flat TVs up to 65"

Wall TV Bracket With Cantilever Arm

Silky smooth cantilever angle adjustment, stays just where you want it to. • Engineered for flat or curved screens up to 65" • Max 600 x 400mm VESA. • Up to 45kg.

$199
HALF PRICE

Rattle the floor boards!

C 5201

180W Subwoofer Sensation!

Add stunning cinema realism to your home theatre sound system. Massive 180W 10" driver with built in amplifier. Size: 490D x 315W x 420H. *Pictured without included cloth grille.

$30
SAVE $9.95

Crystal clear sound!

C 9029

Have a wireless workout!

Sweat resistant bluetooth wireless headphones - ideal for any strenuous activity. Adjustable ear pieces for the perfect fit. Easy on ear buttons for track selection, volume and phone calls. Up to 7hrs from one charge. 15m range.

C 0383

SAVE $15
$40

Tough Drop Resistant Microphone

Thousands sold! Tough grill and diecast body resists damage, even when dropped on hard floors - schools love 'em! Includes 5m XLR lead.

Top Audio Visual Deals

Water proof design

$55
SAVE 38%

D 2039

Brilliant Wireless Bluetooth® Sound

Ask for a demo in-store. • Great for the outdoors, fits into your backpack with ease. • 5 hr playback time • 4000mAH internal battery bank. • Includes USB charging lead (M 8862 wall charger, $16.95) • 268x70x100mm, 840g.

D 5584

Create a multi-zone audio system at home.

SAVE $30
$79

High Quality Wi-Fi Home Network Music Streamer

This brilliant music streamer simply plugs into your existing amplifier's RCA/3.5mm input and pairs with your smartphone or tablet for instant high quality audio streaming.

SAVE 23%
$42

A 1109A

Instant Bluetooth® audio for any amplifier!

Pairs with your phone & stream instantly to your existing audio system. Includes 3.5mm lead. Buy P 6020 1.5m lead ($6) to hook up to RCA input on most amps.

Send TV audio to your head phones!

A 1103B
$54.95

Two Way Bluetooth® Wireless Audio

Transmits or receives audio via Bluetooth 4.1. Can be powered via USB on your TV (cable included). Uses low latency technology so theres no lip sync issues! Includes 3.5mm & RCA cables.

SAVE 33%
$30

L 2026

Boost your telly & radio reception.

This antenna provides 25dB gain for clear digital TV & radio reception. Includes power supply & PAL-F cable.

SAVE 20%

A 3133B $39

Mini HDMI Repeater

Extends HDMI leads up to 50m. Supports 4K @ 60Hz.

SAVE 22%

A 3087B

$39

3 Way HDMI Signal Switcher

A handy HDMI switcher for connecting up to 3 HDMI sources to a 4k/2k or HD display.

SAVE 22%

P 7394

$42

USB C to HDMI Cable

3m length. Hook your phone or laptop up to any HDMI monitor.

Big brand name sound for a fraction of the price!

$299/pr
SAVE $100

C 0870

Opus One® 2x30W Wi-Fi Wireless Ceiling Speakers

Magnetic 'edge to edge' grille.

These stunning high performance kevlar cone speakers offer wireless music streaming by connecting to your home wireless router. Playback can be via stored music, podcasts, Spotify etc. Plus you can install multiple pairs to create multi-zone audio system. Apple Airplay compatible. Sold with active (amplified) and passive speaker. 210mmØ ceiling cutout. 102mm depth.

Why Wi-Fi? Wi-Fi speakers typically offer better range and audio quality than Bluetooth, plus they can be networked into a full multi-zone system which can be controlled by one or a few devices.

Stunning hi-fi clarity for an amazing price!

$224/pr
HALF PRICE!

C 0868

Opus One® 8" Wall/Ceiling Speakers

PLUS BONUS BACKBOXES VALUED AT $45! (C0869)

Featuring woven carbon fibre woofer & titanium dome tweeter for the ultimate in home theatre response! • Bass & treble control switches • Vented magnets • Easy flip-lock installation • Rust free aluminium grilles

Instant, powerful PA sound!

An all in one portable PA sound system with amplifier that sets up in just seconds - no expertise required. Just plug into 240V power, switch it on and connect a mic. USB playback makes it easy to play your favourite tunes. Great for clubs, sports events, fetes, carnivals and bingo nights - any crowd up to 500 people!

$175
C 0991
8" 100W

$239
C 0993
10" 180W

SAVE $60

Add on a C 0520A floor stand to suit for just $20. Normally $39.95

$199
C 8884

Ideal for sports clubs, churches etc.

UHF Wireless Handheld Microphone Pack

WOW, a pro grade package with two handheld transmitters for under $200! Up to 60m range line of sight. Offers wireless freedom without sacrificing speech quality. XLR/6.35mm output. Requires 4xAA batteries.

Iroda® 3 Nozzle Blow Torch Kit

Ideal for trades requiring both precision brazing and high output wide spread flame jobs. Supplied in handy carry case with stable safety stand. 120 mins run time at mid setting. Includes carry case.

Trade quality!

$195

NEW!

T 2457

Iroda® Mini Blow Torch

A 1300°C blow torch with adjustable gas feed for a variety of tasks such as brazing and model making.

$39.95

NEW!

T 2486

Don't forget the gas! T 2451 $8.50.

Take snapshots & record video

S 8747A

Handy Wi-Fi Endoscope Camera

Great for diagnosing problems in hard to reach places, this handy camera has a 3.6m lead with 2 megapixel camera, viewable on your phone or tablet screen. Connects up to 4 devices at once. LED camera light provides a clear view. Includes hook, magnet & mirror attachments. *Phone for illustration purposes.

$89

SAVE $20

$19.95

T 2188

NEW!

1000V Precision Driver Kit

Smaller sizes than most 1000V rated driver sets. Ideal for servicing AC equipment. 3 flat blade (2.0, 2.5 & 3mm) and 3 phillips (#000, #00, #0).

$49.95

D 3009

NEW!

PoE Network Tester

Test live ethernet cabling for data and power. Works with any 802.3af/at ports/cabling. Ideal for data/comms installers.

NEW!

CATALOGUE OUT NOW!

- Over 800 new products.
- 416 pages - our biggest edition ever.

Register to receive a complimentary copy by post at: altronics.com.au/catalogue

Handy Deals For Installers...

Easily add equipment to existing installs!

H 4620 2RU **$39.95** | H 4621 4RU **$67.95** | H 4622 8RU **$129**

Adjustable Wall Mount Folding 19" Racks

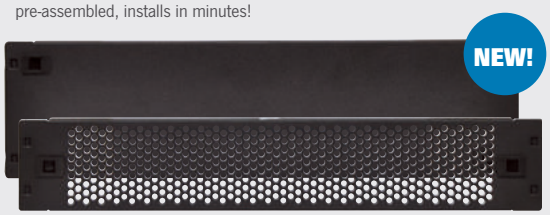
These racks fold out into a wall mount 19" rack for comms and audio installations. Depth can be adjusted between 236 and 400mm. Full pre-assembled, installs in minutes!

SAVE 25%

HD5908 8RU **$99** | HD5912 12RU **$109**

Wall Mount Open Frame 19" Racks

An open frame 19" rack system designed for wall mounting equipment up to 300mm deep. Ideal for combinations of patch panels, security and audio equipment.



NEW!

Time Saver Snap-Fit 19" Rack Panels

Save time and money! No more fiddly cage nuts and bolts to screw in. Just slide in the clip and push fit for a secure fitting between equipment.

Rating	Model	ONLY
1RU Vented	H 5149	$19.95
2RU Vented	H 5150	$27.95
1RU Solid	H 5136	$11.95
2RU Solid	H 5137	$15.95
3RU Solid	H 5138	$19.95

H 5180A

SAVE 25%

$60

19" Rack Mount Power Board

A neat and tidy solution for powering equipment. 2RU panel fitted with powerboard & overload circuit breaker.

SAVE $20 **$79** D 5137A 24 Port

SAVE $50 **$199** D 5139 48 Port

Easy Connect Coupler Cat6a Patch Panels

Easy back to back connection for use with pre-terminated leads. No fiddly punchdown terminals! Includes cable support bar on rear.

$14.95

NEW!

P 8110

Keep Long Cables Neat & Tidy.

Wall mountable cable winder to keep extension leads, audio cables etc stowed safely away. Great for in the service van, shed or workbench. Suits 2-20m of cable.

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WA

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» **Cannington:** 5/1326 Albany Hwy 08 9428 2168
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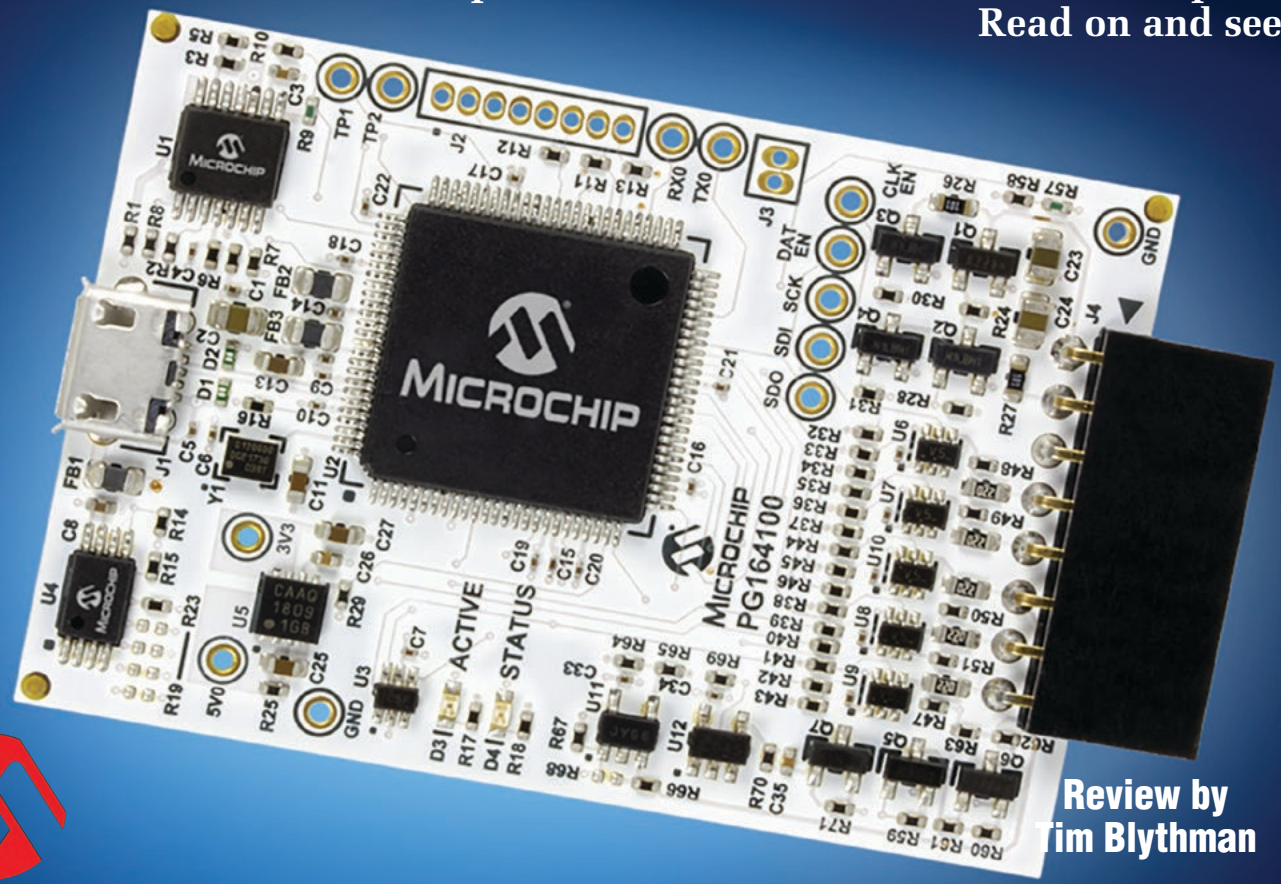
Hot on the heels of the new PICkit 4 comes the Snap Debugger/Programmer, and it's a fraction of the price of a PICkit 4. So how does it compare? Read on and see.



Review by Tim Blythman

MICROCHIP SNAP DEBUGGER/PROGRAMMER

You'd probably recall our review of the PICkit 4 in the September 2018 issue (siliconchip.com.au/Article/11237). We noted that the PICkit 4 is faster than its predecessors, both for programming and debugging.

Clones of the PICkit 2 and PICkit 3 are both in circulation, and given that Microchip has open-sourced the designs of both, the clones appear to work similarly; there is no reason for them to be significantly different to the originals.

Either of these can be had for around $20 from many online sellers.

The Snap is made by Microchip and appears to be selling at a similar price to the PICkit 2 and PICkit 3 clones, so it's worthwhile comparing them. Microchip Direct (Microchip's online store) sells the PICkit 4 for US$47.95, while the Snap is US$14.95.

The Snap Debugger/Programmer is based on the same Atmel SAM E70 32-bit MCU and has the same 8-pin header as the PICkit 4, although it's somewhat less complex, which is how Microchip can reduce the cost compared to the PICkit 4.

For a start, there is no enclosure; all you get is a bare PCB populated with components. But we found a link on the Digi-Key website to download a set of 3D printable case files, at: www.thingiverse.com/thing:3074301 We'll have more on that case later.

Also, the PCB is much smaller than even the PICkit 2, let alone the PICkit 4. Partly this is because it lacks a microSD card socket, so presumably, the Programmer-To-Go function is not available.

There is a QR code stuck to the top of the main IC. It leads you to information on the Snap, at this link: siliconchip.com.au/link/aanq

First use

We are currently using MPLAB X version 5.05 (on Windows 10; Windows 7, macOS and some Linux variants are also supported). This is the

minimum version required to use the Snap, so we didn't have to install any new software.

We then tried to program a PIC32MX170 chip (on a Micromite BackPack), but this failed.

It turns out that the Snap Debugger/Programmer is not capable of providing power to the target, even though there is a checkbox for this in the power settings page.

Once we realised this, we connect an external DC supply to the board and were then able to program the PIC32MX170. The programming speed appears comparable to the PICkit 4, which we expected based on them using a similar SAM E70 processor.

A further peruse indicated that high-voltage programming is not supported either, which rules out its use with many 'legacy' PICs such as the (still in production) PIC16F84A.

So it seems that the main reason for the Snap being so much cheaper is that they've left off some of the features of the PICkit, some of which are mainly for convenience (eg, providing power to the target processor) while others are only needed for use with older PICs.

A closer look

On this basis, we decided to take a closer look at Microchip's information sheet to see what else sets the Snap apart from the PICkit 4. It can be downloaded from **siliconchip.com.au/link/aanp**

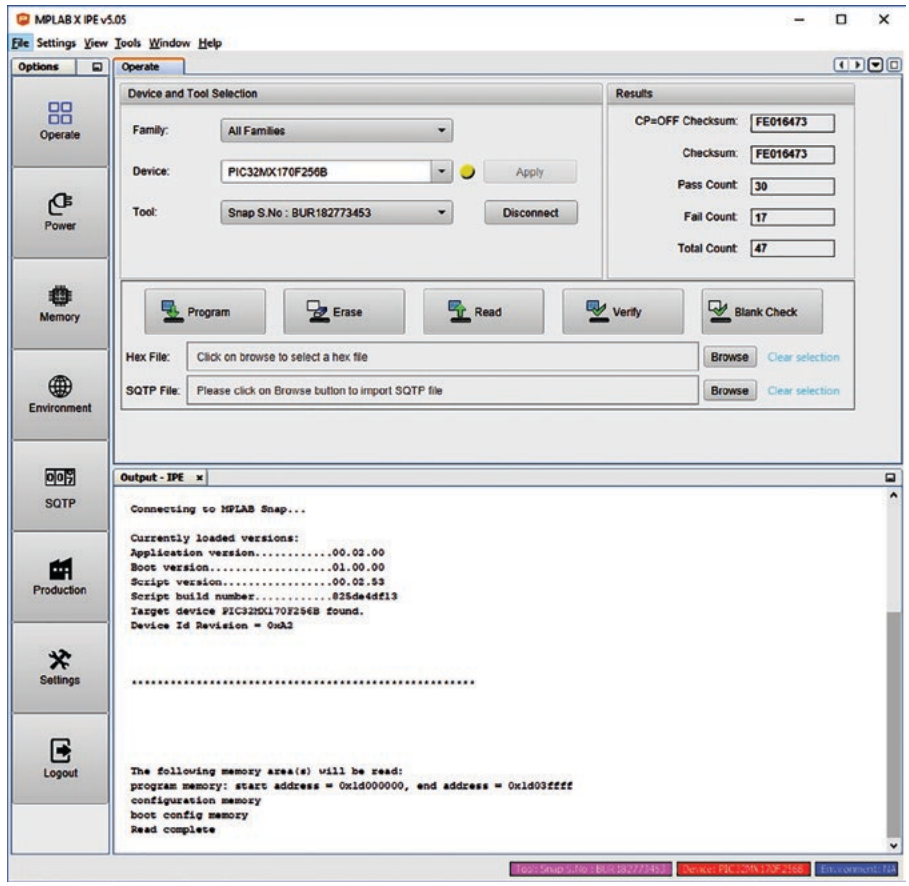
The manual mentions that the emergency recovery jumper is unpopulated; you activate it by shorting the header pins, while on the PICkit 4, a tactile button is provided for this function.

There is also a comparison table between the two programmers (see above right). In particular, the programmable power options are missing on the Snap, as are the configurable pull-ups for the programming pins.

There is an 'interface comparison' which notes that practically the same programming interfaces are available, with the proviso that only the low voltage version is available for some chips.

It also confirms that there is no programmer-to-go feature, and that the Snap is not intended to be a production programmer, while the PICkit 4 is. The PICkit 4 is also claimed to support all Microchip flash-based MCUs, while the Snap supports most.

This is slightly vague, but makes it clear that the Snap is not a direct substitute for the PICkit 4.



Using the IPE (integrated programming environment) version 5.05 with the Snap programmer. It looks similar to when using the PICkit 4; in fact, the only visible difference is the programmer name.

Take it for a spin

Once we'd cleared up the issue of powering the target, we tried a few programming and debugging exercises using many PIC32 devices, including PIC32MX170s and PIC32MX470s in various Micromites, as well as the PIC32MX270 in the February 2019 USB Mouse and Keyboard Interface for Micros (**siliconchip.com.au/Article/11414**).

The speed of working with Snap seemed to be on par with the PIC kit, so if you only need to work with PIC32 devices, the Snap could be a good choice. We checked the device support list for MPLABX 5.10, and it appears that the Snap now supports most (but not quite all) PIC32 devices to some extent.

Programming 8-bit & 16-bit PICs

Next, we tried the PIC16F1455, which has appeared most notably in the May 2017 Microbridge project (**siliconchip.com.au/Article/10648**) and as the USB/serial interface of the Micromite Backpack V2 (May 2017; **siliconchip.com.au/Article/10652**) and the USB Digital Interface Module (November 2018; **siliconchip.com.au/Article/11299**).

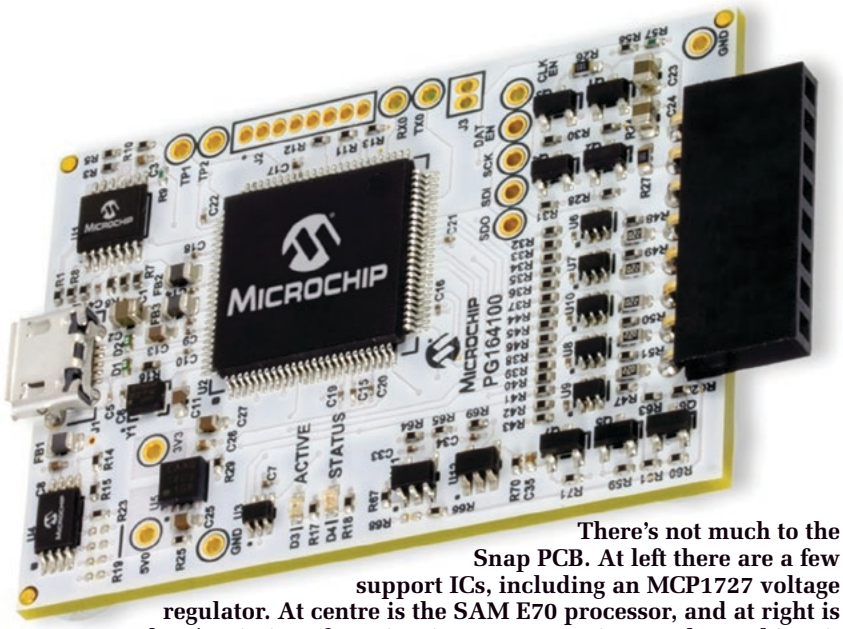
Initially, we tried a chip that had already been programmed for the Digital Interface Module, but could not get the Snap to communicate with it. Using a PICkit 4, we found that the LVP (low voltage programming) option on that chip had been disabled.

After using the PICkit 4 to reset this, we found that Snap could happily read and program the 16F1455. As noted earlier, the Snap cannot do high-voltage programming.

Other 8-bit PICs such as the 12F617 and 16F84 require high voltage programming, so we did not try to program these. As expected, the device support list (for both MPLABX 5.05 and 5.10) indicates that these devices are not supported by the Snap tool.

Give me power

We note that the Snap board has pads for 3.3V, 5V and GND easily accessible, so it may be possible to rig



There's not much to the Snap PCB. At left there are a few support ICs, including an MCP1727 voltage regulator. At centre is the SAM E70 processor, and at right is the I/O pin interface circuitry. In comparison to the PICkit 4, it lacks high voltage circuitry and target power supply amongst others.

up a jumper wire to provide power to the target board if necessary.

These pads are next to a DFN-8 chip marked as U5, which is an MCP1727 voltage regulator.

The MCP1727 is capable of 1.5A, although its power dissipation while dropping 5V down to 3.3V would bring it close to its thermal limit. In any case, the typical 500mA limit of the USB is sure to come into play long before 1.5A is reached.

We 3D printed one of the Digi-Key-designed cases, just to protect the unit from damage.

Before we fitted the case, we noted that the board appears to get quite warm, even when idle.

As it is, we've left the lid off the case for now, as we don't want it to overheat.

There appear to be some other spare pads around the board, including a pair of test points, another pair marked RX0 and TX0, a small pitch 8-way header marked J2, a small pitch 2-way header marked J3 and a row of five headers marked for synchronous serial data of some sort.

None of these are noted in the information sheet, so we can only speculate as to their purpose; they may be for some as yet, unreleased feature.

Our verdict

The Snap Debugger/Programmer is clearly an economy device intended to be used with newer microcontrollers, especially as it cannot work at all with older devices that require high-voltage programming.

Part support is still in progress. It appears that many parts are still only at the preliminary or beta stage of support, including those we have tested.

Nonetheless, we found that they worked fine for programming and simple debugging.

If you are only working with 32-bit PICs, the Snap appears to be an economical option which provides practically all the upsides of the PICkit 4, as long as you can live with providing power to your target micro independently of the programmer.

If you plan to use other devices, we would not recommend it.

There are a small number of 8-bit devices that it supports, such as the 16F1455, although some of these parts offer high voltage and low voltage programming.

This means the Snap programmer would work if the chip is configured with low voltage programming disabled.

But keep in mind that the low-voltage programming can typically only be disabled when using a high-voltage capable programmer, so you should be safe to use these parts with the Snap.

Overall, it's ideal as an economical first programmer, or as a second device to carry with your laptop or notebook, although we would recommend taking a good look at the device support list before making a decision. SC

Feature	MPLAB Snap	MPLAB PICkit 4
Enclosure	No, exposed PCB	Yes
USB Powered	Yes	Yes
USB Speed	High	High
USB Cable supplied	No	Yes
Programmable VPP	No	Yes
Programmable VDD	No	Yes
Emulator Power	No	Yes
Power to Target	No	Yes - 50 mA
Voltage Monitoring	No	Yes
Current Sensing	No	Yes
Target Power	Yes	Yes
Target Voltage Boost	No	Yes
RGB Indicators	LED	Yes
Software Breakpoints	Yes	Yes
Breakpoints	Complex	Complex
Buffered Pin Drivers	Yes	Yes
Configurable pull-ups	No	Yes
Drag and Drop Programming	Yes	Yes
Programmer to Go	No	Yes
Production Programmer	No	Yes
Products Supported	Most Flash MCUs	All Flash MCUs
Pay-Per-Feature	No	Yes
I^2C DGI	Yes	Yes
CDD UART	Yes	Yes
SEE configuration (boot)	Yes	Yes
SPI DGI	Yes	Yes
USART DGI	Yes	Yes
USB Serialization	Yes	Yes
Recovery Method	PCB pads	Pushbutton

MPLAB SNAP vis MPLAB PICkit 4 comparison.

A low-cost 3.5-inch touchscreen for the Arduino & Micromite

by Tim Blythman

We've published many projects using 320x240 pixel, 2.8-inch colour touchscreens. We love them because of their low cost and ease of use. But sometimes they're a bit *too* small! Now we've discovered larger, higher-resolution displays that only cost a bit more and are almost as easy to drive. Where do you get them . . . and how do you use them with an Arduino or Micromite?

While we were working on the Diode Curve Plotter project, published in the March issue (siliconchip.com.au/Article/11447), we thought that it would be nice to have a larger display area for the graphs.

The 5in (13cm) display that we've used with Explore-100 based projects such as the DAB+/FM/AM radio (January-March 2019; siliconchip.com.au/Series/330) is fantastic – but it's quite expensive and a bit larger than is really required for many projects.

There is a similar 4.3in (11cm) screen, but it's hardly any cheaper than the 5in display.

And both the 4.3in and 5in screens have another problem: they use a parallel interface, which takes up a lot of I/O pins, and the regular Micromite doesn't have support for parallel displays.

You need to use the Micromite Plus, which means soldering an SMD microcontroller.

What we really wanted was a larger, higher-resolution screen that uses the same serial control interface as the 2.8in (7cm) ILI9341-based screens that

have been so popular. That would give us more screen real estate and more pixels, without using up any more I/O pins.

And that's just what we found.

We have been aware of the existence of 3.2in (8cm) and 3.5in (9cm) touchscreen modules for some time, but in the past, all the ones we'd seen had a parallel interface.

That's good for providing a fast update rate, but it requires a micro with a parallel interface and plenty of pins to use efficiently.

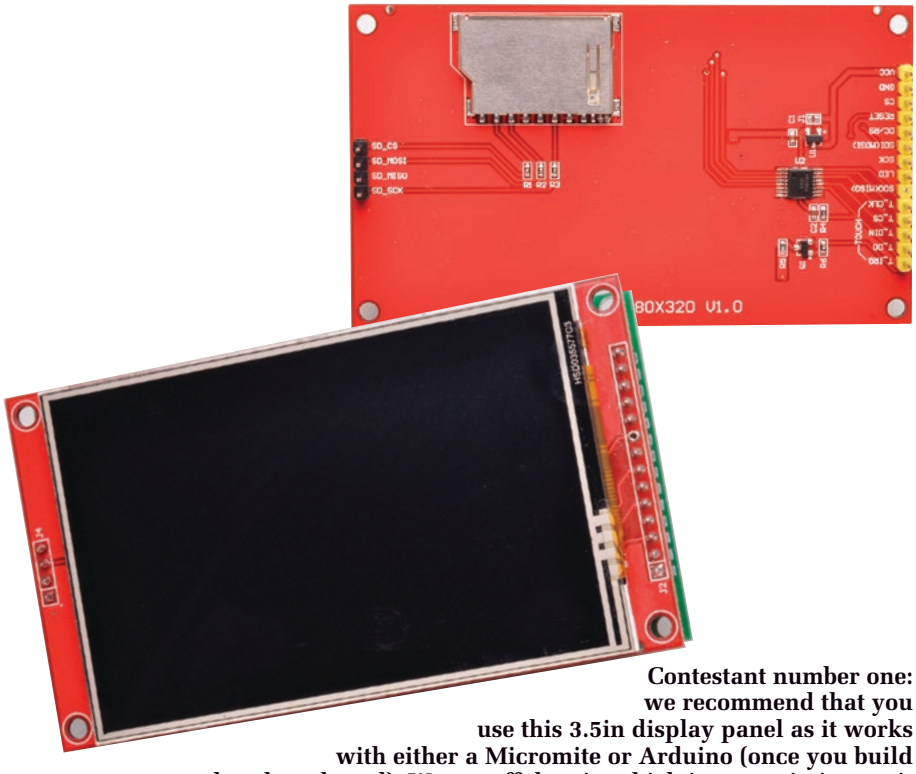
So we went searching for similar serial-controlled screens, and we found two vendors in AliExpress offering just that (see www.aliexpress.com/item//32954128438.html and www.aliexpress.com/item//32954240862.html).

We bought one from each to test.

There are several different variants of this type of display around, with different connectors and interfaces, but all use 0.1in (2.54mm) pitch header pins to connect to the controller board. Many sellers indicated that they use the ILI9488 controller IC, although, as we found out later, this is not always the case.

They all come with either a full-size SD or microSD socket onboard, and many have a resistive touch panel too. We particularly wanted to get the touchscreen variants since that obviates the need to fit any buttons or other controls in most cases.

Once we got the screens, it took quite a bit of effort to get them working (for reasons we'll explain later), but we got there in the end. Later on, we'll give you download links to our software and source code, so that you can do it too.



Contestant number one: we recommend that you use this 3.5in display panel as it works with either a Micromite or Arduino (once you build our breakout board). We cut off the pin which is now missing, as it was causing a conflict between the touch and display controllers, but that is no longer necessary with the revised breakout board we present in this article.

We also decided to try out some other similar screens, one from Altronics (because it was easy to get) and another which is designed to plug straight into an Arduino, since that one is really easy to get up and running if Arduino is your platform of choice.

This article assumes that you are familiar with either the Arduino Integrated Development Environment (IDE) or Micromite BASIC and the various possible methods of uploading MMBasic code to a Micromite.

If you are not, we suggest that you try working on simpler projects with these platforms before diving into this one.

We have designed a small breakout board to connect the 'universal' 3.5in serial touchscreen (ie, the one that does not come as a 'shield') to an Arduino.

We'll describe this board below. This breakout board also works with the 2.8in touchscreen that we've used so often in the past in the Micromite LCD BackPack.

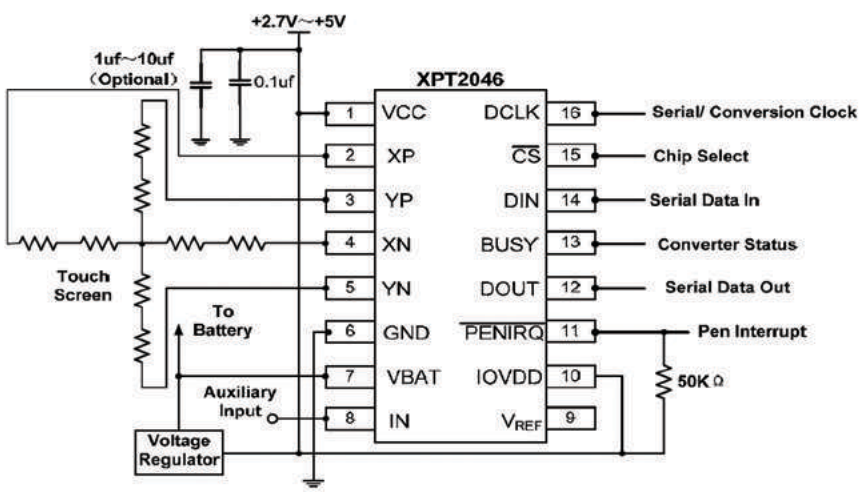


Fig.1: this excerpt from the XPT2046 datasheet shows a typical circuit for the chip and demonstrates how the touch panel can be viewed as a variable resistor network.

Contestant number one: 3.5-inch serial touchscreen

The 3.5in serial touchscreens we sourced look very similar to the 2.8in touchscreen used in the very popular Micromite LCD BackPack project (February 2016; siliconchip.com.au/Article/9812).

The screen is not only bigger but it also has a substantially higher resolution, at 480x320 pixels (0.15MP) compared to 320x240 pixels (0.07MP). So

it has exactly twice as many pixels.

As you would expect, given the extra 0.7 inches (20mm) of diagonal screen size, it is slightly larger, and the PCB is slightly longer, so the two pin headers on the board are around 13mm further along than in the smaller LCD. The mechanical mounting holes are also arranged differently.

Otherwise, the main 14-pin interface header appears identical, and the pins are marked with the same designations. Like the 2.8in display, you can get these with or without the touch panel. The difference in price is small, so we think it's worthwhile to get the one that has it.

The main appeal of this unit is that it can plug into the existing Micromite BackPack and even if you're using it with an Arduino Uno, it won't take up all that many digital I/O pins, so you will still have plenty left for other tasks.

It's controlled using two SPI interfaces, one for the display and one for the touch panel, although you can drive both from a single set of SPI pins on the micro. Like the 2.8in LCD used with the Micromite BackPack, the full-size SD card socket is accessible from one of the long edges of the PCB.

To simplify our experiments on these displays with Arduino boards, we designed the aforementioned breakout PCB that suits both the 2.8in 320x240 display and the 3.5in 480x320 display.

The instructions for assembling this breakout board can be found below. If you have one of these displays and an Arduino board, you might want to build this board before reading the following usage instructions.

Getting it working with an Arduino

Because of the prevalence of Arduino libraries, we started our testing using our breakout board with an Arduino Uno. After a few attempts, we found a library that was able to drive the display. This library can be found at https://github.com/jaretburkett/ILI9488 (see Fig.4)

We had to change the pin assignments in the example sketch, named "graphicstest" to the following:

```
#define TFT_CS     10
#define TFT_DC     9
#define TFT_LED    -1
#define TFT_RST    8
```

There is no pin '-1', but this value can't be empty, so a value of -1 is used because this is ignored by digitalWrite commands since it is an invalid pin number, and therefore has no effect. On our board, the LED pin is hardwired to the 5V rail, forcing the LCD backlight on, to save as many pins as possible for other uses.

Interestingly, this library was modified from another library designed for the ILI9341 controller, which is what is in the 2.8" inch displays.

It simply provides a low-level interface to the "Adafruit_GFX" library. This library provides common, high-level functions like drawing shapes and text to displays.

Adafruit has developed a good number of display boards and modules (many of which are now appearing as clones), and they have excellent support for their displays.

Their libraries are a great resource for getting many displays running.

While it's nice to have some library code that works, we wanted to know how to control these displays at a much lower level and get an understanding of their operation.

To see what sets the larger ILI9488-based displays apart from the smaller ILI9341s, we added some code to the libraries to print out (to the serial monitor) what commands and text were being sent to the board, formatting this output as commands which could be pasted directly into the Arduino IDE. This is shown in Screen1.

This showed us the required initialisation sequence for the display controller. We then checked the ILI9488 datasheet (http://siliconchip.com.au/link/aanr) and confirmed that the commands that were being issued were appropriate.

There are a few commands that require a delay after they are sent, to allow the controller to process the data, so we needed to know when these should occur.

We could then build a working sketch from scratch to drive the display.

Since the ILI9488's drawing (as opposed to initialisation) commands are practically identical to those for the ILI9341, once it's initialised, the process of drawing on the screen is quite straightforward.

Although the datasheet hints that a 16-bit colour mode (as used with the ILI9341) is available, it doesn't appear to work in SPI mode on the ILI9488, so we had to modify the code to produce 24-bit colour values.

We've distilled all this code down to just the essentials and put it in a demo sketch titled "SPI_320x480_display_demo". This demonstrates drawing on the screen in all four orientations, including region fills, text and lines made of individual pixels.

Micromite support

We were then able to translate this Arduino sketch into working Micromite BASIC (MMBasic) code. We had to do a search and replace to change Arduino's "0x" hexadecimal prefix with "&H" to suit BASIC, as well as changing the function definitions to subroutines, amongst other changes.

The demo BASIC file is called "SPI_320x480_display_demo.bas".

For the Micromite, the font data is embedded as a CFUNCTION. While this directive is usually used to store machine code, it can be used to store any binary data for MMBasic, and is a more compact way of doing this than DATA statements.

Some of the display routines have been modified to work with larger arrays of data, as the SPI interface works more quickly with arrays than individual values.

Before this improvement, clearing the screen took nearly a minute.

This display code would be an ideal candidate for a CFUNCTION, as that would allow it to work a lot quicker, but the intention here is to demonstrate what is possible, and also to show how the interface works.

We expect readers will have an easier time understanding the BASIC code than the equivalent C code, even if the C code would be substantially faster.

If you are using the Micromite Plus BackPack, use the source files with the "MMplus" suffix at the end. The SPI2 peripheral is used for display communications on the Micromite Plus, so you may need to run an "OPTION … DISABLE" command if there are any other peripherals using SPI2 before the display code will work.

Similarly, on the regular Micromite, any OPTIONs that lock the SPI bus may need to be disabled before using our sample programs.

Note that we have not designed a breakout board to interface this screen to a Micromite.

That's because it can be plugged

straight into the 14-pin header socket on a Micromite LCD BackPack (V1 or V2). The mounting holes don't line up, but we're sure that our readers will figure out clever ways to mount these boards successfully.

Touch interface

One of the great features of these displays is the touch interface.

A quick inspection shows that like the 2.8in touchscreen we're familiar with, the 3.5 inch screen uses the same XPT2046 touch controller IC and the connections appear to be practically identical.

We even found some schematics which indicated that this was the case.

The XPT2046 touch controller is effectively a multi-channel 12-bit analog-to-digital converter (ADC), which is intended to be connected to a four-wire touch panel. It can drive its analog pins as needed to supply a voltage difference across the touch surface. Fig.1 shows a typical connection for the XPT2046 IC.

An 8-bit command is sent to the XPT2046 over the SPI bus, which sets up the drivers and ADC multiplexer and starts an ADC conversion.

This conversion is clocked (timed) by the following pulses on the SPI SCK clock line.

Twelve bits of data are read out from the chip, along with four zero bits (for a total of 16 bits or two bytes), after which the touch controller is ready for another conversion.

So this is all pretty straightforward, and we had code which worked with the 2.8in touch panels, but it would not work with the 3.5in panels.

We tried many different approaches to solve this, including probing the lines going to the touch panel itself, and ultimately we discovered that the problem was due to the LCD controller and touch controller sharing one MISO (master in slave out) line.

The display controller should not be driving this pin when its $\overline{CS}$ (chip select) line is high, as this is how multiple devices share an SPI bus.

The touch controller correctly leaves its MISO pin floating when its $\overline{CS}$ line is high. But the LCD controller appeared to be driving MISO all the time, and this was preventing the touch controller from pulling it high, resulting in the micro receiving all zeros.

The fix was easy; we disconnected the LCD controller's MISO line entirely, as it is not needed since we never read data back from the LCD controller. Then, everything worked like a charm.

The final Arduino shield design has a jumper to disconnect this pin from the SPI bus, so you should be able to get the touch controller working simply by leaving it open.

Once we got the touch interface working, we wrote a few more sample programs (both Arduino sketches and Micromite BASIC). One of these is a basic demo and the other provides test and calibration features.

They are named "SPI_3.5_inch_TFT_shield_demo_wth_touch.bas" and "SPI_3.5_inch_TFT_touch_calibration.bas", with the Micromite Plus equivalents having the same names but with "MMplus" at the end.

SD card support

Like the smaller 2.8in display modules, the 3.5in displays also have an SD card socket connected to a separate set of pins via 1kΩ resistors. As there is no direct connection to these pins on the Micromite or Micromite Plus BackPack, the only way to access the SD card with these boards is by adding jumper lead connections.

Our Arduino breakout board has headers to make connections to the SD pins for both the 2.8in and 3.5in displays.

And since the display module has nothing to prevent 5V being fed into the SD card pins, we have designed the breakout board to do all the level conversion, as this is also needed for the display and touch controllers.

The Arduino IDE provides a basic "SD" interface library, and we tried the "listfiles" example from (Files -> Examples -> SD).

Our design uses digital pin 6 as the SD card chip select line, so we simply changed one line in the **"listfiles"** sketch to use the correct CS-bar pin like this:

```
if (!SD.begin(6)) {
```

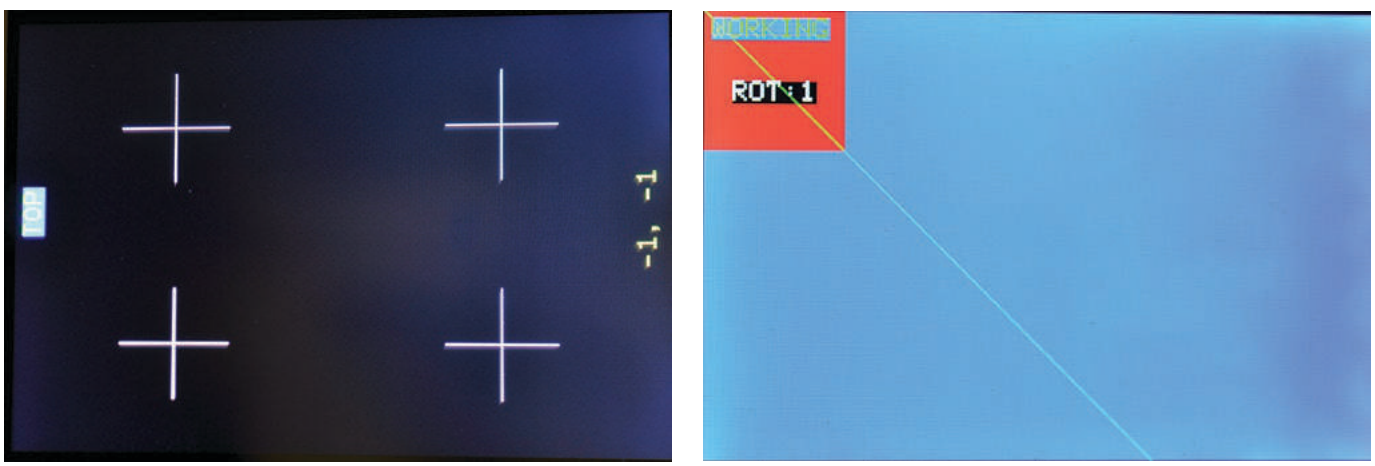
We were then able to retrieve a list of the files from an SD card plugged into the socket on the display. Our breakout board can also be used to read data from SD cards.

Verdict

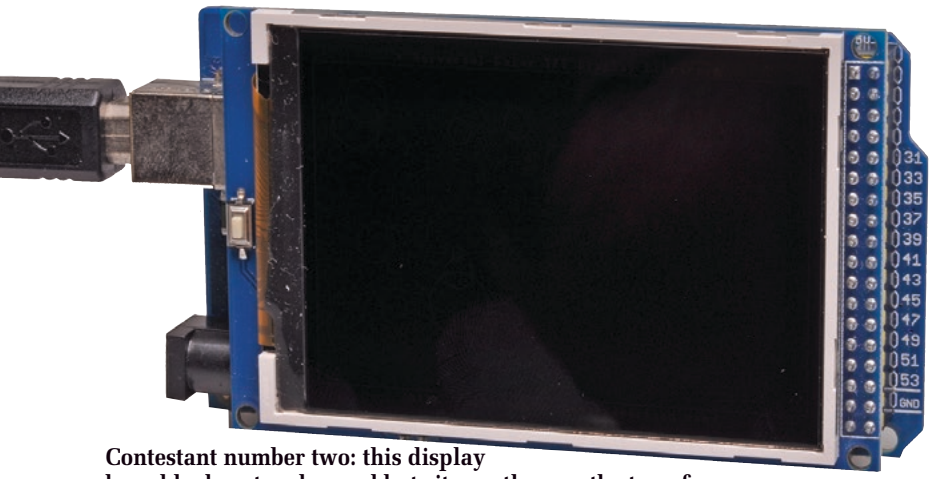
Now that we've figured out how to drive it and use the touch panel, this display is an excellent choice, especially for use with Arduino boards.

And since it can also be used with both the Arduino and Micromite boards, we hope to use it more in the future. The SPI interface means that the pin usage is minimal.

We'll need to come up with some CFUNCTIONs if we hope to use this



These are the test patterns you will see when you run our sample programs. The shadowing (particularly on the right photo) is an artefact from photography – this is almost invisible with the naked eye.



Contestant number two: this display board lacks a touch panel but sits neatly over the top of an Arduino Mega. The tactile switch resets the connected microcontroller when pressed.

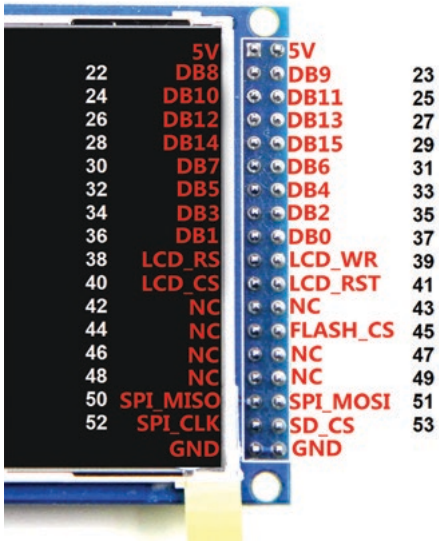


Fig.2: a pin map for the Altronics display shield, designed to plug into an Arduino Mega. We have added the Mega pin numbers for clarity, although these are not needed for the direct port writes used in the library code.

display to any extent with the Micromite, as the BASIC interface is quite slow.

But the BASIC code is certainly a good starting point, and may be sufficient for some applications.

Before we get to the assembly of the breakout board for this display, let's take a look at a couple of other candidates that we evaluated.

Contestant number two: Altronics Z-0575

The next board is a 3.2 inch LCD screen with no touch panel. It's designed to plug into an Arduino Mega, and it is available from Altronics, Cat Z6527 (www.altronics.com.au/p/z6527) as well as other sources. Altronics say that it has an ILI9481 controller IC, and they appear to be correct, as it works with Arduino libraries designed for that controller chip.

This display has a 16-bit parallel interface and is designed to work with contiguous port pins on the Arduino Mega, meaning that, in theory, it will is capable of very fast communication using direct port writes.

But that also makes it virtually impossible to use with a regular Arduino or a Micromite.

Its header layout is interesting. There is a long 2x18 pin header at one end, which suits the large header block at one end of the Mega.

There is also a small 2-pin header which connects to the 3.3V and $\overline{\text{RESET}}$ pins at the other end of the Mega. This requires the display to rest on the USB socket for support while blocking practically all of the other pins.

Interestingly, the full-size SD card socket is deep inside the board outline and is not accessible while the board is attached to a Mega.

On the same side as the SD card socket are three small SSOP ICs (which are responsible for converting between the Arduino's 5V logic levels and the display's 3.3V) as well as a capacitor, resistor, voltage regulator and an unpopulated SOIC-8 footprint.

The specification sheet notes that the display will work from 3.3V to 5.5V, so it might also be suitable for 3.3V boards such as the Arduino Due, although we have not tried this.

On the front of the display is a tactile pushbutton, which is connected between the GND and $\overline{\text{RESET}}$ pins on the Mega board, so that pressing it resets the microcontroller on the Mega board.

Getting it working

Altronics provide a good amount of sample code, which can be downloaded from the downloads tab of the product page linked above.

This download includes manuals, libraries and images of sample display output.

We used an Arduino Mega to test it, mainly because most of the other micro boards we had on hand didn't have enough I/O pins to drive it – you need 20 I/O pins just to run the display, and even if you have that many free, it would be fiddly to wire it up using jumper leads (see Fig.2).

The board is effectively a shield for the Mega and directly plugs in on top. While easy to insert, the large header is hard to remove, and we found we had to take care detaching the shield by wiggling the display to gently ease the pins out so that they don't catch and bend.

We extracted the "Arduino Demo_Mega2560" folder from the zip file and copied the contents of the "Arduino Demo_Mega2560\Install libraries" folder to the Arduino libraries folder. In Windows 10, our libraries folder is at "Documents\Arduino\libraries".

We then had a libraries folder as shown in Fig.3.

It appears these libraries are adapted from those that can be downloaded from www.rinkydinkelectronics.com/library.php This is a handy website which also offers fonts that can be used with graphical LCDs.

We restarted the Arduino IDE for it to recognise the newly copied libraries.

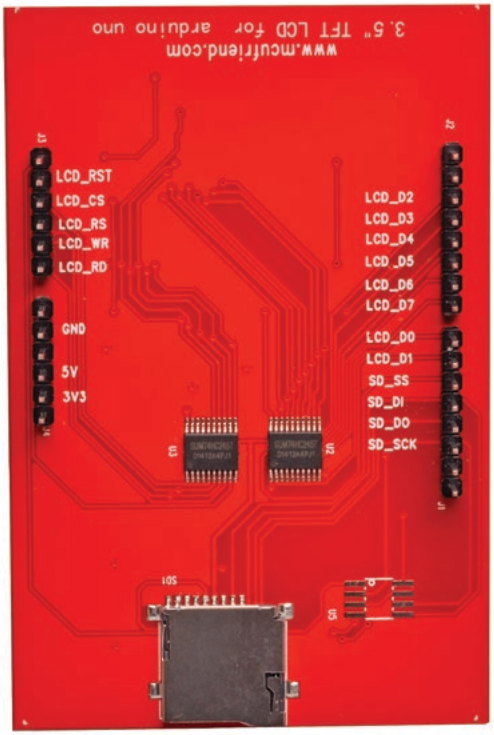
The example sketches can be found in the "Arduino Demo_Mega2560" folder. The "Example01-UTFT_Demo_480x320" sketch cycles through a few demonstration patterns.

The other sample sketches demonstrate fonts, buttons and bitmaps, although, as we noted earlier, this display does not feature a touch panel, so it was not possible to test the button sketches properly.

SD card slot

As we mentioned, there is an SD card slot tucked under the board.

This can be a handy as it allows



Contestant number three: while this display module does have a touch panel, the lack of available spare pins when paired with an Uno means that it may not be very useful, as the Arduino can then not easily be connected to any other device.

large images, graphics or icons to be stored on an SD card instead of taking up valuable flash memory in the microcontroller.

Once again, we tested it with the "**listfiles**" example from **Files -> Examples -> SD**.

Although the pin map on the diagram does not have the pins numbered, we were able to ascertain that the SD card's CS-bar pin is connected to pin 53 on the Mega.

Thus we needed to change the line

```
if (!SD.begin(4)) {
```

to read

```
if (!SD.begin(53)) {
```

before compiling and uploading the sketch. It then worked, showing a listing of all the files on an inserted SD card, so the SD card slot on this board works as expected.

The unpopulated footprint noted earlier is designed to be fitted with a flash memory IC.

It too uses the SPI bus, and according to the specification sheet, uses the Mega's pin 45 as its $\overline{CS}$ (chip select) line.

There is no further information on how this should be used, although we would not be surprised if the footprint matches many of the commonly available flash memory ICs.

In summary, this display is easy to get, looks good and works well with the provided libraries.

The lack of a touch panel limits its utility somewhat, as does the awkward placement of the SD card slot. Being slightly smaller than the other two screens but with a similar pixel count, it does offer a slightly higher pixel density.

Contestant number three: 3.5 inch with Arduino pinout

The final display we tried is a 3.5in touchscreen with a standard Arduino shield pinout, and it gives a very tidy result when plugged into an Arduino Uno (see above).

The display's PCB sits flush with the USB socket on the Arduino board, and the microSD card slot fits neatly next to that USB socket.

On the back of the PCB, along with the microSD card slot, there are two SSOP ICs (presumably for level conversion) and an unpopulated SOIC footprint.

The SD card and SOIC-8 footprint appear to be connected directly to the board's I/O pins and not via the level converter ICs.

The PCB itself is only marginally wider and longer than the display. So when combined with an Arduino Uno, it's quite compact.

But because this display uses an 8-bit parallel interface, it uses up many of the available pins.

With the Uno, only a single analog pin and the serial communication pins are left free. That rather limits the utility of the combination!

So you would need to use it with a Mega in practical applications, which rather negates its compactness advantage, and also would require significant software changes that would slow it down.

The board is marked with 'mcufriend' branding, and this hint led us to find some helpful tools to work with the module.

We tried code designed to interface to the ILI9488 controller in parallel mode (which it supposedly used), but that didn't work.

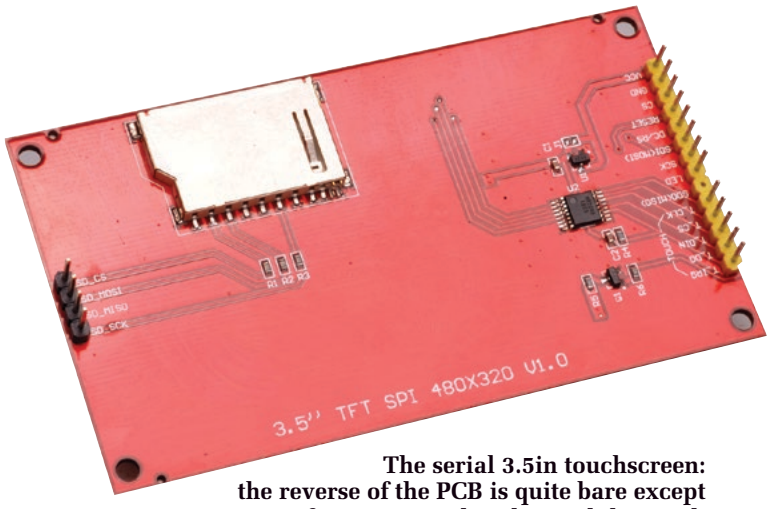
Since the seller advised that the display could have one of a few different controller ICs, we decided to figure out which one it actually had.

There is an excellent resource at **siliconchip.com.au/link/aans** – this is a tool designed to help identify and operate these shield-type displays.

At the time of writing, the most recent update to this tool/library was only four days prior, so it appears that it is continually being updated. It also requires the "Adafruit_GFX" library, and it can identify and control a large number of different displays.

Both the "Adafruit_GFX" and "MCUFRIEND_kbv" libraries can be found and installed from the Arduino IDE's library manager. Screen2 shows how you can find and install these library dependencies using the Arduino Library Manager.

We then opened and ran the "graph-



The serial 3.5in touchscreen: the reverse of the PCB is quite bare except for an SD card socket and the touch controller IC and its associated components.

The circle highlights the pin we had to remove during testing to resolve a conflict on the SPI bus (also shown at left). You shouldn't have to do this on your board!

ictest_kbv" sketch from the File -> Examples -> MCUFRIEND_kbv -> graphictest_kbv menu. This displays some information to the serial monitor at 9600 baud, including an identification code which is read from the board. In our case, the code was 0x6814.

According to the "MCUFRIEND_kbv.cpp" file in the library, this suggests that the controller in an RM68140, which is similar to the ILI9488 but has a different initialisation sequence.

In our case, this demo code initialised the display and drew various test patterns, indicating that this sketch is capable of working with this display board.

We took a look at the RM68140 data sheet but opted for a sneaky trick to work out the initialisation sequence, without having to read it in depth.

We embedded some extra code into the library mentioned above to see what commands and data were being issued to the display, then copied these back to our sketch. This resulted in a working example sketch, named "8bit_320x480_display_demo".

Our download package also has a cut-down version of the MCUFRIEND_kbv library demo sketch. You will note that the sketch produces similar results to our example, but is much larger due to the library having many features that aren't used.

Our sample code is designed to work on an Arduino Uno board. Due to differing port and pin configurations, it will not work on other Arduino boards; it depends on direct port access for speed.

The sketch includes some code that should work on other Arduino boards, but it is very slow and has been commented out for simplicity

Touch panel

The touch panel on this type of display is a simple four-wire resistive type. It doesn't even have a dedicated controller IC, but instead, connects directly to the Arduino analog I/O pins.

You can determine the touch location setting one of these pins to 5V (high), another to GND (low), and then performing an ADC read on either of the two remaining pins. The resulting value indicates the relative position of the touch in the X or Y axis.

So the touch panel effectively behaves as a two-dimensional potentiometer, with the "wiper" actually being the point being touched.

As two of the wires are connected to the horizontal edges and two to the vertical edges, the location in two dimensions can be found by performing two readings as described above, but changing which pins are driven and which are sampled.

On this panel, the touch panel is connected to pins D6, D7, A1 and A2. Interestingly, all of these pins are also used for driving the display, so this is a very busy shield. This does not interfere with their touch functions.

We've written a basic sketch that reads from the touch panel and displays the raw ADC readings on the screen. It's called "8bit_320x480_touch_demo".

These ADC readings would need to be converted into display coordinates to implement a functional interactive

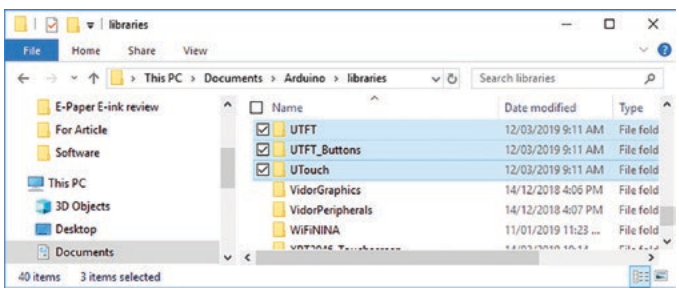


Fig.3: after unzipping the Z6527 resources from the Altronics website, the library files should look like this. The three selected folders starting with "U" are the ones being copied.

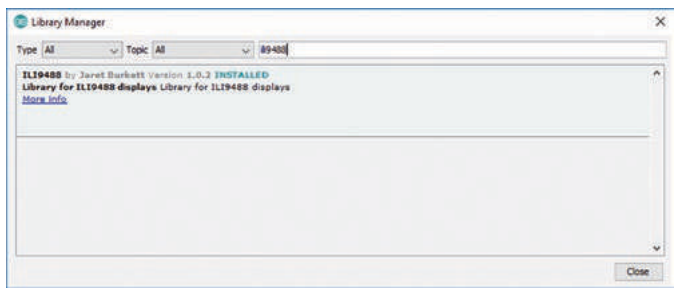


Fig.4: the ILI9488 library from https://github.com/jaretburkett/ILI9488 can be installed using the Arduino Library Manager by searching for "ili9488".

touch interface, which in turn would require a calibration procedure, to account for differences in displays.

We've also provided a sketch called "8bit_320x480_touch_calibration", which shows the basics of how to do this conversion and gives you a starting point for doing it.

microSD card slot

Even though the SD card socket on this display appears to be wired directly to the Arduino's I/O pins (and thus, would be driving a 3.3V device from 5V outputs), we tried the **"listfiles"** sketch as above, but this time changing the initialisation line to read:

```
if (!SD.begin(10)) {
```

to suit the Uno's pin mapping. Surprisingly, it worked. We suspect that we have a tough microSD card and would be surprised if it lasts long being directly driven from 5V pins.

The SOIC-8 footprint on the board also appears to be directly connected to 5V I/O pins as well, with its pin 1 (which is $\overline{CS}$-bar on many flash ICs) connected to pin A5 on the Uno.

Verdict

As noted above, this unit looks very tidy when paired with an Uno board, but since it leaves virtually no I/O pins free, it's hard to think of a useful application for it.

And as also mentioned above, if you use the obvious solution of upgrading to an Arduino Mega board, you lose most of its speed advantage over a serial display, since you can no longer do direct port writes.

That the shield appears to connect to the microSD card slot and flash chip pins at 5V is concerning, and we would not recommend using those interfaces on these modules.

Building the Arduino breakout board

We are very happy with the 3.5 inch SPI display panels (the first ones described above). We felt that a proper breakout board was necessary to make it easier to connect them to an Arduino, avoiding the need for messy jumper wires. The circuit for this board is shown in Fig.5.

There isn't much to it. It mainly just routes the signals between the Arduino and display, while converting the Arduino's 5V signal swing to 3.3V to suit the LCD screen, touch panel and SD card interfaces.

There are seven 470Ω /1kΩ resistive dividers to achieve this. These are for the MOSI and SCK connections on the shared SPI bus, three $\overline{CS}$ lines (one each for the LCD, touch controller and SD card) and two extra control lines on the LCD controller; DC (data/command) and RESET.

Note that we haven't put a divider on MISO since it is a 3.3V signal coming out of the touch controller (or SD card), which a 5V Arduino boards can accept as-is. Per the data sheet, the minimum voltage level that an ATmega328 micro running from 5V is guaranteed to read as high is 3.0V.

The board also supplies logic power (3.3V) to the display, which is taken from the Arduino's 3.3V supply, and power for the backlight LED(s), which comes directly from the Arduino's 5V supply.

The touch controller's T_IRQ line is not connected, as we felt that this would eat too much into the already dwindling number of available I/O pins on the Arduino.

We have provided connection pads to all unused pins on the Arduino, so they can be connected by jumper lead if needed. In most applications, we find that it is not necessary.

The SPI communication lines for the display are routed to the 6-pin ICSP header on the Arduino board. Since the introduction of the so-called 'R3' Arduino board layout, this is the location which is guaranteed to be connected to the Arduino's hardware SPI pins, regardless of which digital I/O pins they map to (that differs between various Arduino boards).

For this reason, the breakout board can be used with just about any 5V Arduino R3 board, and we've tested it with a few including the Leonardo, Mega and Uno.

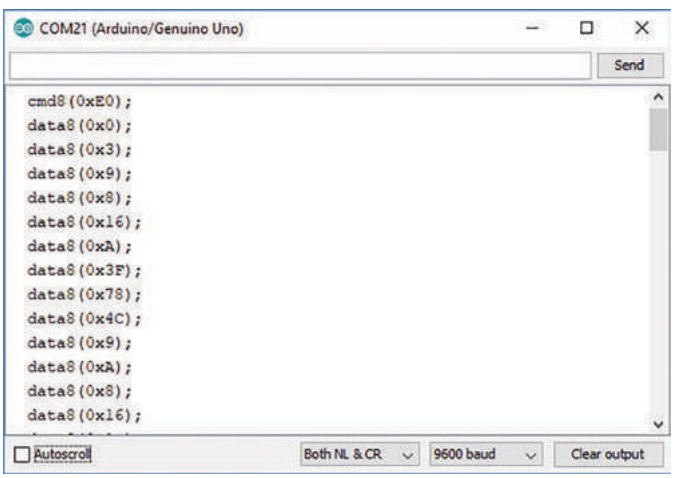
If you're not sure that your board is R3 compatible, check that it has the ICSP header approximately halfway between the TX/RX pins and the analog pins. It should also have one 10-way, two 8-way and one 6-way female pin headers.

Earlier versions typically lack the 10-way header.

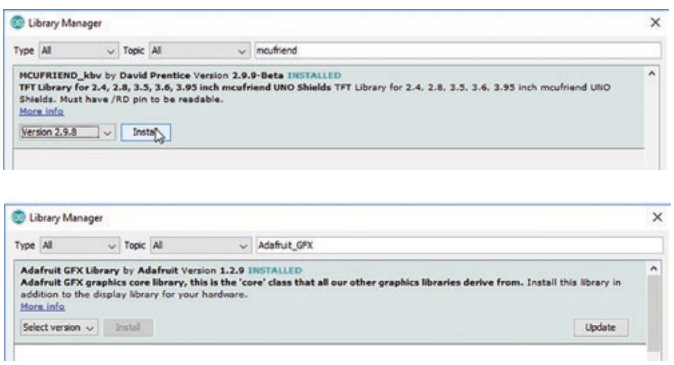
As mentioned earlier, JP1 can be used to connect the MISO line to the LCD controller, but generally, you will want to leave this open, or else the touch controller interface may not work.

The PCB also has mounting holes for both the 2.8 inch and 3.5 inch display panels, as well as the Arduino board itself. The remaining spare room is occupied with a small prototyping area with 5V, 3.3V and GND connections nearby, and all unused Arduino pins have adjacent breakout pads.

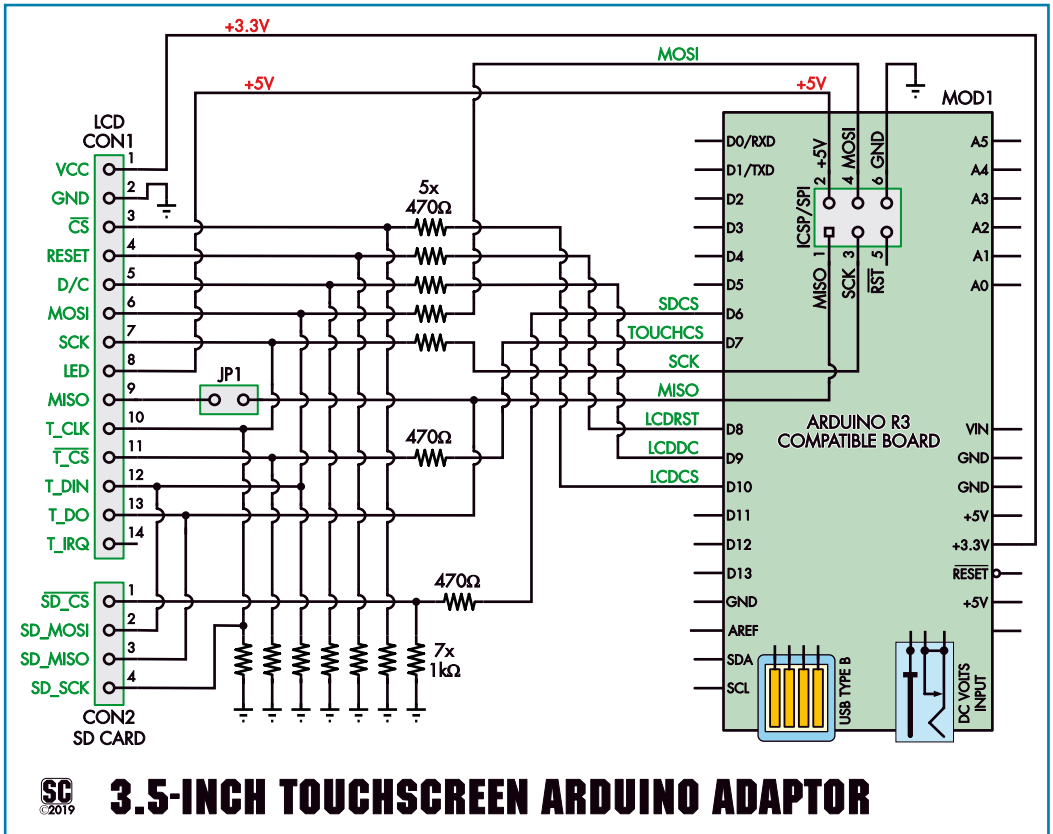
There's also a slot which allows the end of the PCB to



Screen1: this Arduino code was generated by software running on the Arduino itself, after we added carefully crafted debugging code to the library which was able to initialise the LCD controller successfully.



Screen2: both the Adafruit_GFX and MCUFRIEND_kbv libraries can be installed through the Arduino IDE's Library Manager. Use the search terms above to help find them.



SC ©2019 **3.5-INCH TOUCHSCREEN ARDUINO ADAPTOR**

Fig.5: the breakout board circuit routes the connections between the Arduino pins and LCD touchscreen headers, while providing level translation to allow the 5V Arduino to drive the 3.3V chips on the LCD board. This conversion is done using 1kΩ /470Ω resistive dividers.

be broken off if you are using it for the 2.8in display, as otherwise the board is 13mm wider than it needs to be.

Construction

The breakout board PCB is coded 24111181 and measures 98 x 55mm. Use Fig.5, the PCB overlay diagram, as a guide during construction.

If you wish to cut down your board to suit a 2.8in displays, this should be done first, to avoid damage to installed components. Run a sharp knife over the four tracks crossing the narrow bridge to cut them cleanly. This avoids any risk of them tearing and lifting off the board.

Now use broad-edged pliers to gently flex the board along the line of the slot until it breaks. You may like to clean up the rough edges with a file; we recommend doing this outside, preferably with a face mask to avoid inhaling fibreglass dust.

The resistors are the first parts to fit, where shown in Fig.6. The 1kΩ resistors will have colour bands of either brown-black-red-gold or brown-black-black-brown-brown, while the 470Ω resistors will have either yellow-violet-brown-gold or yellow-violet-black-black-brown.

You can leave the header for JP1 off (you probably won't need it) but if you do want to install it, do so now. You can mount the header but leave the shunt off at first if you aren't sure.

Next, fit the five headers which connect to the Arduino board. The easiest and neatest way to do this is to use the Arduino board itself as a jig.

Plug the 6-way, 8-way, 10-way male headers and the 2x3-way female header into the Arduino board and then slot the breakout board on top. Ensure it is flush and pushed down firmly before soldering the headers into place. All these header pins are soldered from the top side of the board.

Check the headers are correctly soldered, and unplug the breakout board from the Arduino board.

Use a similar technique for the headers that connect to the display panel, although you may find that your display panel does not come with the 4-pin male header fitted.

Assuming this is the case, plug the 4-way male header into the 4-way female header, then plug the 14-way female header onto the display panel's pin header.

Put the 4-way male header end into the display panel and rest the breakout board on top, ensuring that all 18 header pins are in their correct locations.

Now solder the headers onto the breakout board and then flip the assembly over to solder the 4-way male header to the display panel. The breakout board is now complete and can be plugged back into the Arduino.

Optionally, you can use tapped spacers and machine screws to secure the display panel to the breakout board. Mount the spacers to the display panel with the spacers behind and the screws on top. Fit the breakout board to the rear of the display panel, and secure with the four remaining screws. There will be a slight gap between the male

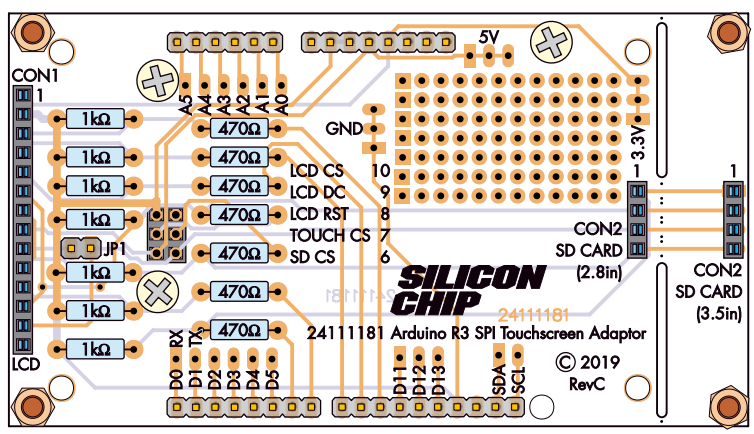
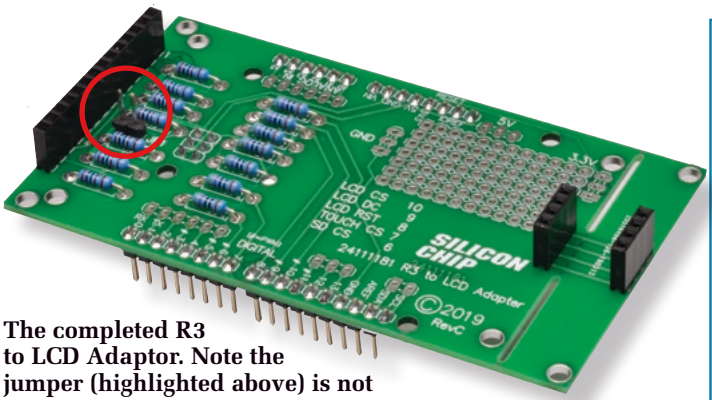


Fig.6: use this PCB overlay diagram as a guide when building the breakout board. After fitting the resistors where shown, you just need to solder the headers in place. Some go on the top while those which plug into the Arduino are mounted on the bottom.



The completed R3 to LCD Adaptor. Note the jumper (highlighted above) is not populated and we have fitted headers for both 3.5 and 2.8 inch displays, although you will probably only use one (fit one or the other). If using the 2.8 inch display, you can break this PCB along the slots at the right side.

and female headers as the 12mm spacers are longer than the approximately 11mm combined height of the headers, but they should still make good contact so this shouldn't cause any problems.

Software

The sketches we have created are designed to stand on their own and do not require any separate libraries to be installed. The ZIP download package contains three sample sketches, all starting with "SPI".

Extract the contents of the .zip file to somewhere on your computer, and open one of the files with the Arduino IDE. Select the appropriate board and port combination, and click "Upload". The three examples work as follows:

1) **"SPI_320x480_display_demo"** draws boxes, lines and text to the display as it cycles through the four possible orientation settings (two in portrait and two in landscape).
2) **"SPI_3.5_inch_TFT_shield_demo_wth_touch"** shows off the touch feature by drawing lines and displaying the current touch coordinates to the display.
3) **"SPI_3.5_inch_TFT_touch_calibration"** can be used to fine-tune the touch settings, although we found the default calibration worked fine with three different screens.

The touch calibration sketch requires the Arduino Serial Monitor to be running. During the calibration stage, it will send four lines of text to the Monitor that should be copied over the similar lines in any sketch that uses these touch routines.

For example:

```
#define TOUCH_X0 1
#define TOUCH_X1 2001
#define TOUCH_Y0 199
#define TOUCH_Y1 76
```

You might also like to experiment with the library we mentioned earlier, remembering to change the pin definitions near the start of the "graphicstest" sketch like this:

```
#define TFT_CS    10
#define TFT_DC    9
#define TFT_LED   -1
#define TFT_RST   8
```

The library can also be installed via the Library Manager by searching for "ili9488" (see Fig.4). It also requires the "Adafruit_GFX" library to be installed, which can be found by searching for its name in the Library Manager.

In the software resource bundle for this project, we've included .zip files of the current versions of these open-source libraries in case you have trouble finding them.

Future updates

Now that we have confirmed that these displays can be used on both the Arduino and Micromite platforms, we plan to use them in future projects.

Before we use them with a Micromite, we will need to write CFUNCTIONs to get an acceptable display update speed. SC

Parts list – Arduino breakout board

1 double-sided PCB coded 24111181, 98x55mm
1 3.5in 480x320 pixel ILI9488-based LCD touchscreen with SPI interface
1 Arduino R3-compatible board, such as the Uno R3, Mega R3 or Leonardo R3
1 10-way pin header
2 8-way pin headers
1 6-way pin header
1 4-way pin header
1 14-way female header (CON1)
1 4-way female header (CON2)
2 3-way female header strip ***OR***
3 2-way female header strips
4 12mm-long M3 tapped spacers
8 6mm M3 panhead machine screws
1 2-way male header strip and jumper shunt (JP1; optional)

Resistors (all 1/4W 1% or 5%)
7 1kΩ *(brown black red gold or brown black black brown brown)*
7 470Ω *(yellow violet brown gold or yellow violet black black brown)*

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CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

Battery-powered Steam Train Whistle

John Clarke's September 2018 Steam Train Whistle & Diesel Horn is a fantastic project. But I wanted to build it for my young grandchildren, so I needed to modify it to be battery-powered with automatic switch-off. In the off mode, the current drain should be no more than 2µA for good battery life.

You could achieve this with a battery on/off switch, but in my experience, young children always forget to turn it off and so the battery would soon be flat.

I decide to use a standard 9V battery, two 5V regulators and a PIC12F617 microcontroller as a switch-off timer. In sleep mode, it draws practically no current.

REG2 is an ultra-low quiescent current (~1µA) regulator which provides the 5V supply for microcontroller IC4. After 12 seconds, IC4 goes into sleep mode, giving a total battery current of less than 2µA. In this state, output pins GP4 and GP5 (pins 3 and 2) are low (0V), switching off N-channel Mosfets Q1 & Q3 and PNP transistor Q2, so that no current is fed to REG1, an LP2950 5V regulator.

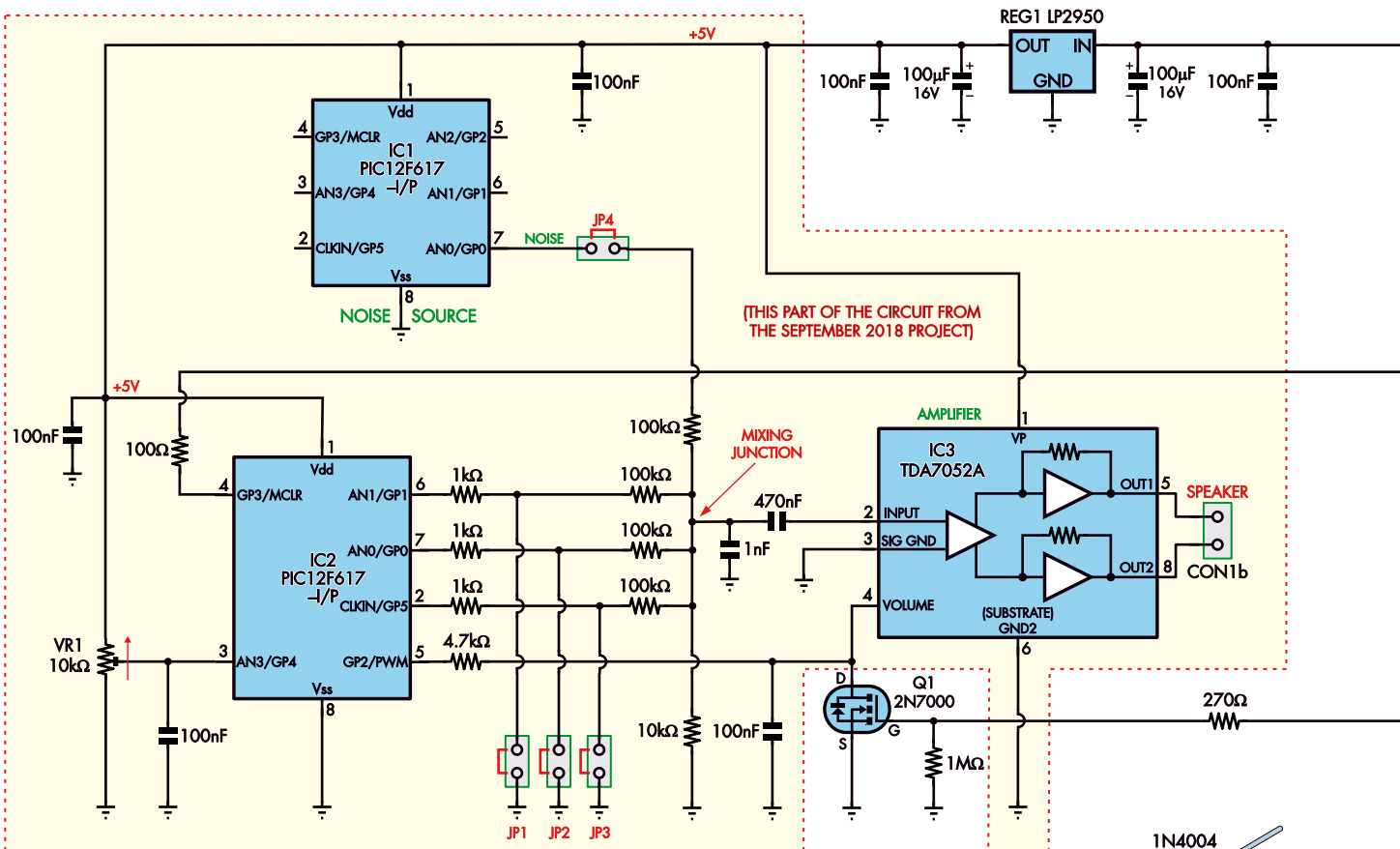
When SOUND pushbutton S1 is pressed, it pulls the GP2 input (pin 5) of IC4 low, bringing it out of sleep mode. The GP5 output then goes high, switching on Q1 which mutes the amplifier (IC2). At the same time, GP4 goes high, switching on Mosfet Q3 which pulls current from the base of Q2, turning it on and allowing current to flow to REG2.

REG2 then brings up the 5V rail supplying IC1-IC3. After a short time, GP5 is brought low again, releasing the mute (which is required to prevent clicks while the other ICs power up), and output GP0 is driven high, triggering the whistle or horn sound effect. If pushbutton S1 is pressed again a short time later, GP0 again goes high, re-triggering the sound effect.

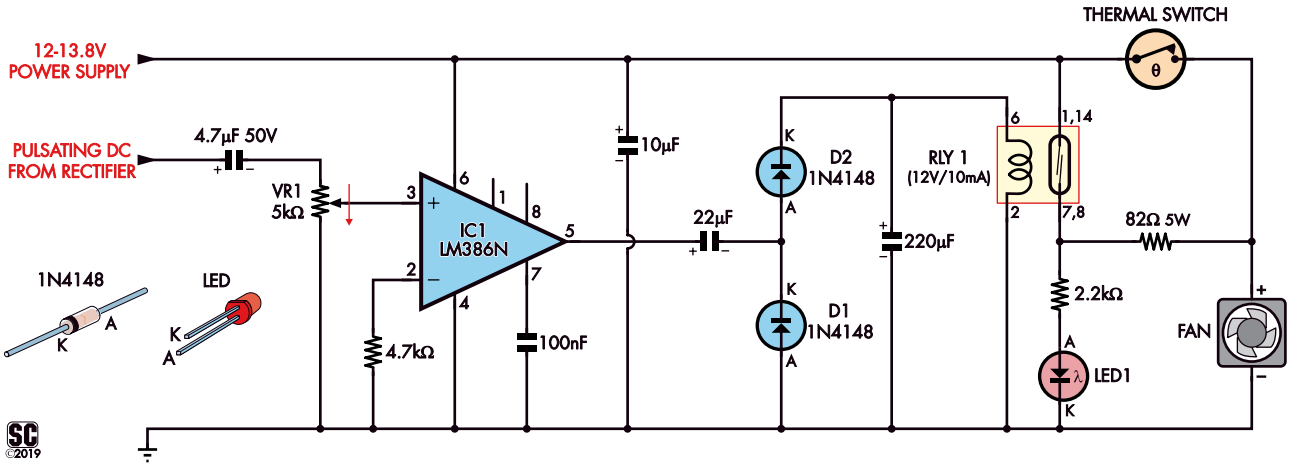
If S1 is not pressed for 12 seconds then microprocessor IC4 goes back to sleep, switching off the power to the rest of the circuit and again reducing the battery current to less than 2µA.

The software for IC4 was written in PICBASIC PRO, and the BASIC source code ("Whistle sleep.bas") and HEX file ("Whistle sleep.HEX") are available for download from the SILICON CHIP website.

Les Kerr,
Ashby, NSW ($70).



SC ©2019 **BATTERY POWERED STEAM WHISTLE**



Switching cooling fan based on power supply load

I built a 12V 10A power supply for general purpose use, but most of the time it is used for float charging a 12V lead-acid battery which runs LED lighting. The supply needs a cooling fan when under heavy load but I didn't like the fan running continuously when it's only putting out a few hundred milliamps to keep the battery charged during the day.

I decided to add circuitry to switch the fan on when the supply is delivering more current but rather than use a shunt to monitor the load, I came up with a simpler solution.

This circuit monitors the ripple voltage on the capacitor bank that's supplied by the main rectifier and which feeds the regulator portion of the supply. The higher the load, the greater the ripple, so this is a good way to control the fan.

I'm using an LM386 amplifier (IC1) to amplify the ripple. VR1 provides a means to adjust the amount of amplification and therefore the load threshold at which the fan switches on.

The output of the LM386 is fed to a diode charge pump based on D1 & D2 which results in a DC voltage proportional to the AC ripple voltage.

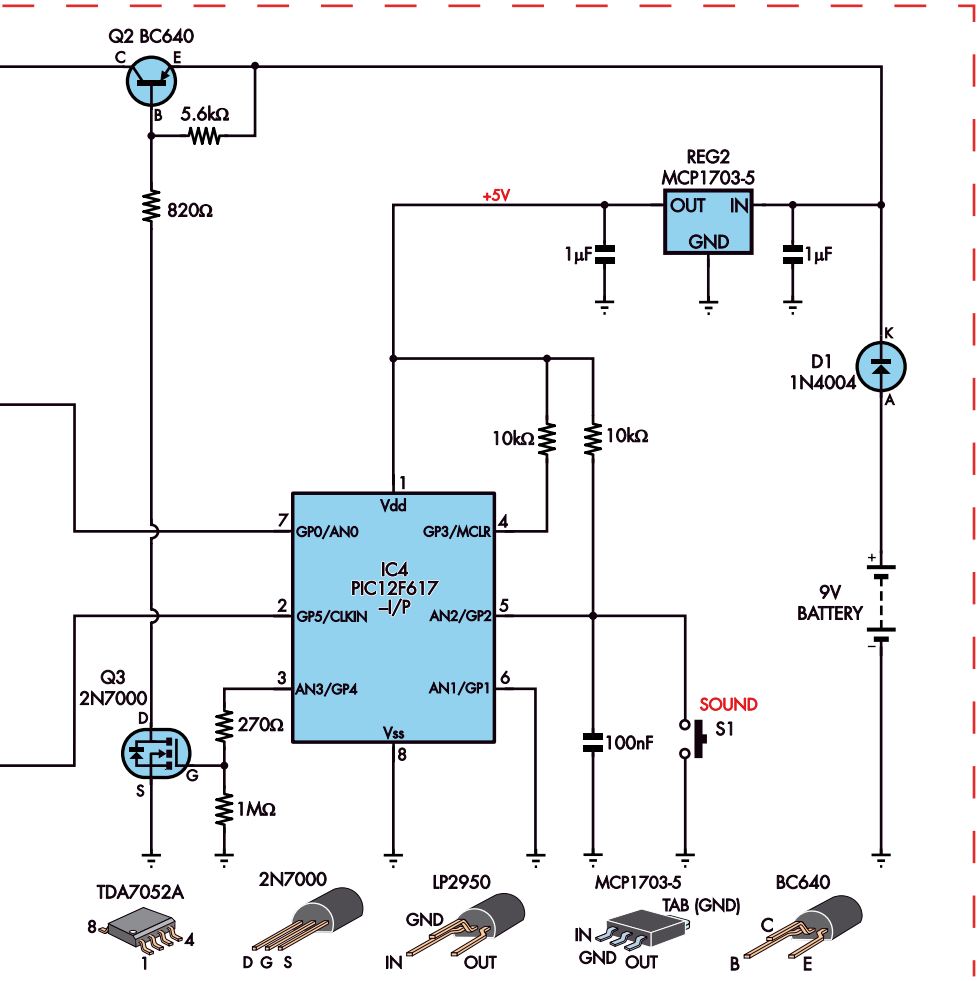
This is applied to the coil of RLY1, so once the output of the charge pump exceeds the relay's switching threshold (around 3V for the 5V relay), it latches on, lighting LED1 and powering the fan.

A thermal switch on the heatsink is used as a failsafe, to power the fan if the heatsink temperature gets too high, eg, if the load is somehow drawing very high current pulses which are too brief to trigger the ripple-monitoring circuitry but still high enough to cause considerable heating.

If the thermal switch closes, the fan runs at full speed; the rest of the time, it's either off, or running at a slightly reduced speed due to the 82Ω series resistor. This reduces noise while still providing adequate cooling in most usage cases.

To set up the circuit, draw a constant load from the supply at the level you want the fan to switch on (I chose 3A), then rotate VR1 full anti-clockwise and then slowly clockwise until the fan switches on, as indicated by LED1. Assuming your supply has an adjustable current limit, you can do this by shorting the outputs and then adjusting the current to the desired level.

Trevor Vieritz,
Burpengary, Qld ($65).



ESP32 Internet Radio Receiver

The low-cost VS1053 MP3 player shield featured in the July 2017 issue (siliconchip.com.au/Article/10721 & siliconchip.com.au/Article/10722) and available from the SILICON CHIP Online Shop (Cat SC4315; siliconchip.com.au/Shop/7/4315) gave me the idea to make my own internet radio.

All I needed was an Arduino with WiFi to receive the data; then I could use the VS1053 to decode and play it. In the end, this internet radio cost me less than $20 to build.

The software on the Arduino barely has to do anything at all; once it's receiving the compressed audio data from the remote radio server, it just passes it on to the VS1053 audio processor on the shield board, and it does the rest! I found that all I have to do is deliver streaming data in exactly 32-byte chunks for this to work.

As I'm familiar with the Arduino-compatible ESP32 processor and board modules, and they are cheap, that's what I decided to use. Once I took advantage of some helper libraries and headers, the simple version of my program ended up only being about 50 lines long.

The hardware is similarly quite simple. The three main components are the ESP32 board, VS1053 shield and optional OLED display.

The ESP32 and VS1053 connect via a three-wire SPI serial bus, two chip select lines (XCS and XDCS), a reset pin (XRST) and interrupt/signal line (DREG).

The SPI pins of the shield go to the ESP32's SPI bus, while the other lines simply go to available digital I/O pins. The OLED communicates via I^2C and so it is wired to the ESP32's I^2C pins (SDA for data and SCL for clock).

The VS1053 shield I used is similar to the one described in the July 2017 issue of SILICON CHIP, but instead of being an Arduino shield, it is a roughly square blue board with all the connections on a SIL header along one side. This makes it smaller and more convenient to wire up to the ESP32 module I'm using.

The 3.3V supply is derived from a 3.7V (nominal) LiPo cell by an HT7333 low-dropout 3.3V linear regulator.

The ESP32 and optional OLED screen run off this regulated rail while the VS1053 has internal 3.3V and 2.5V regulators, so the battery voltage is applied directly to its 5V input, which feeds directly to the inputs of these two regulators (see the July 2017 article for its circuit details).

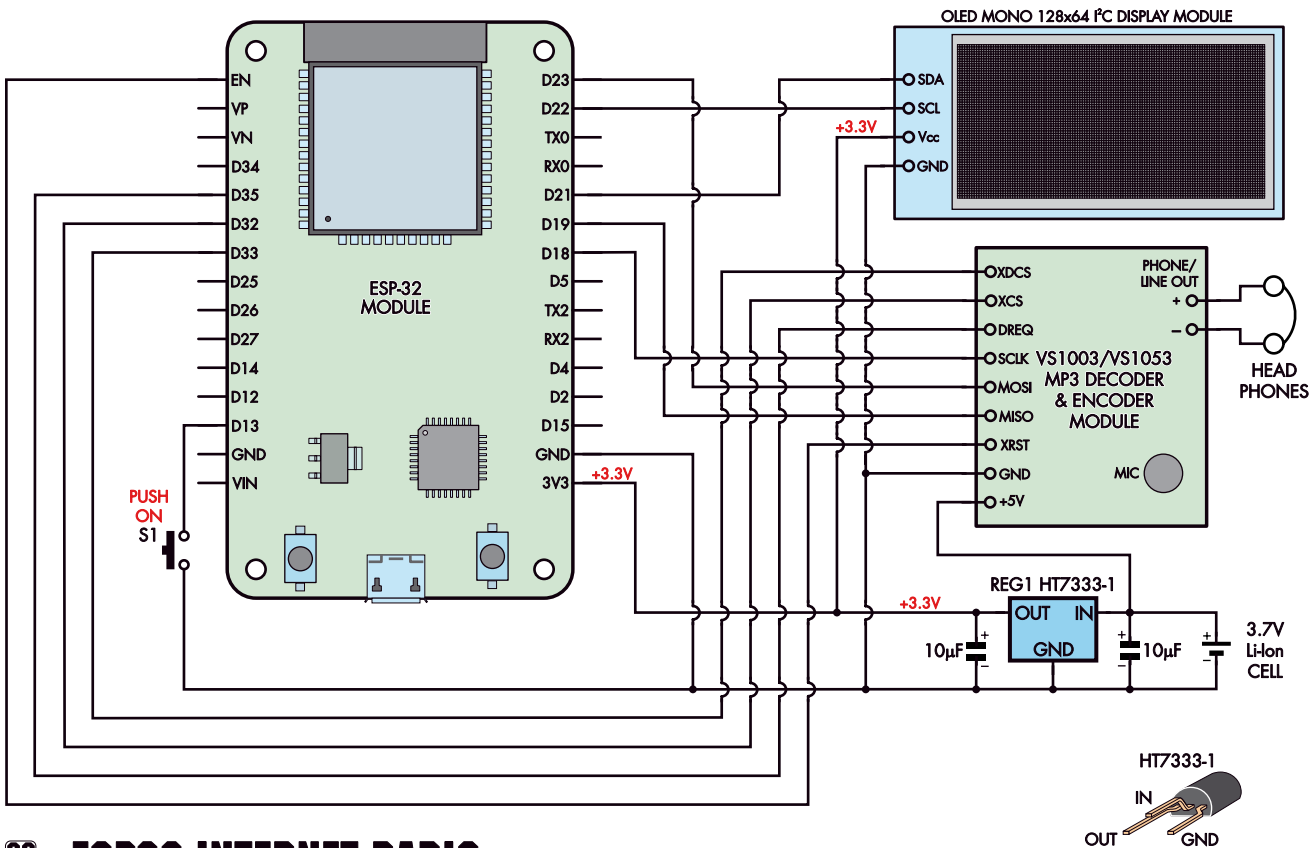
Pushbutton switch S1 is connected between ESP32 pin D13 (reset) and ground and it used to change radio stations; each time it is pressed, it resets the ESP32 and it then tries to connect to the next internet radio station from a list stored in flash memory.

When building the unit, keep the wires between the ESP32 and VS1053 as short as possible. Longer wires can result in a humming noise at the audio output.

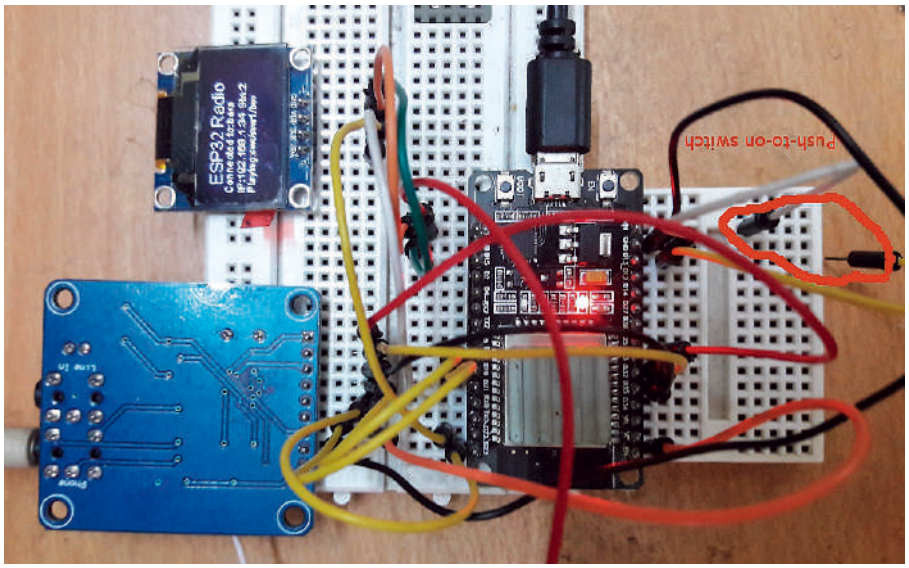
The VS1053 module produces stereo sound which can be fed directly to headphones or small speakers. For driving larger speakers, which require more than a watt or so, you need an external amplifier.

Once you've built the hardware, you will need to download and install the latest Arduino integrated development environment (IDE) if you don't already have it on your computer.

You will also need to download and install the ESP32-specific board files. This can be done via the built-in Board Manager.



SC ©2019 ESP32 INTERNET RADIO



The radio was built on a breadboard using flying leads, the size and pin locations of the modules makes it difficult to lay them out cleanly, but it could be built into a case.

The software sketch requires the open-source ESP32 VS1053 library, which is included as part of the download package (github.com/Edzelf/Esp-radio).

Open the sketch in the Arduino IDE and then modify it so that it contains your WiFi network SSID and password. These are defined near the top of the code.

You should also change the station list to include your favourite internet radio stations. You can then upload the software to the ESP32 in the usual Arduino way.

Once uploaded, the ESP32 will first display "Hello" to indicate that the VS1053 is up and ready. It will then wait for a couple of seconds while it connects to your WiFi network.

Progress is shown as a series of dots on the Serial Terminal output. Once connected, it then loads the station and as soon as it's connected, you should get audio output from the VS1053 module.

Press switch S1 once and the next station will be tuned. It will go through the connection process again, and this may take a few seconds.

If you've connected the optional I^2C OLED screen, the name of the currently playing station is shown on that screen. I had to jump through some hoops to get this part of the code to work.

I first tried using the Adafruit SSD1306 and Adafruit GFX libraries to drive the display, which I've had success with in the past, but they interfered with the radio streaming and caused the sound to break up.

I found that I had to instead use a lightweight SSD1306 library called esp8266-oled-ssd1306 (also included in the download) which is designed specifically for ESP8266-based modules.

With this library, the I^2C display works just fine without any effect on the sound output.

Note that if you leave the OLED screen off, you don't need to change the software. The I^2C data will just go nowhere.

The sketch is named "simple_esp32_radio_mod3.ino" and a second file, "helloMp3.h" is also included which contains a short greeting sound file that's played at start-up.

Bera Somnath,
Vindhyanagar, India ($95).

Circuit Ideas Wanted

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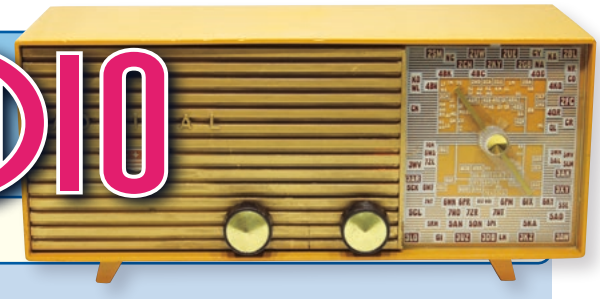
VINTAGE RADIO

By Associate Professor Graham Parslow



The 1956 Admiral 5ACW valve-based clock radio

The Admiral 5ACW differs in its shape and technology from other radios made by major Australian brands in the 1950s. Plastic-case mantel radios of the time typically had rounded edges. The rectangular simplicity of this radio was to become the norm in the 1960s.

The most radical feature of the 5ACW is the incorporation of a printed circuit board (PCB) that hosts most of the major components.

One of those components is an encapsulated package with seven inline pins connecting all components between the audio preamplifier and output pentode; it's the orange package next to the 6AQ5 valve.

This radio incorporates a synchronous clock driven by the 50Hz mains that controls timed on-off and snooze. The other front panel knobs are for volume adjustment and tuning.

The addition of a clock made this radio especially welcome in kitchens and bedrooms. In bedrooms of the time there were few power outlets installed; probably only one for a bedside lamp. To avoid using a double adapter, this radio incorporated an unswitched outlet on the rear panel, so a lamp could be daisy-chained.

The gold-accented front panel is a separate moulding, distinct from the main case, and acts as a speaker grille for the 4-inch MSP speaker mounted in its centre.

The same radio was also offered without a clock. The alternative front panel covered the clock area while the speaker remained in the centre. The clockless radio does not include a mains socket at the rear; a blanking plate covers the hole.

This radio was available in various colours: ivory (shown here), primrose, grey, burgundy, beige and tan.

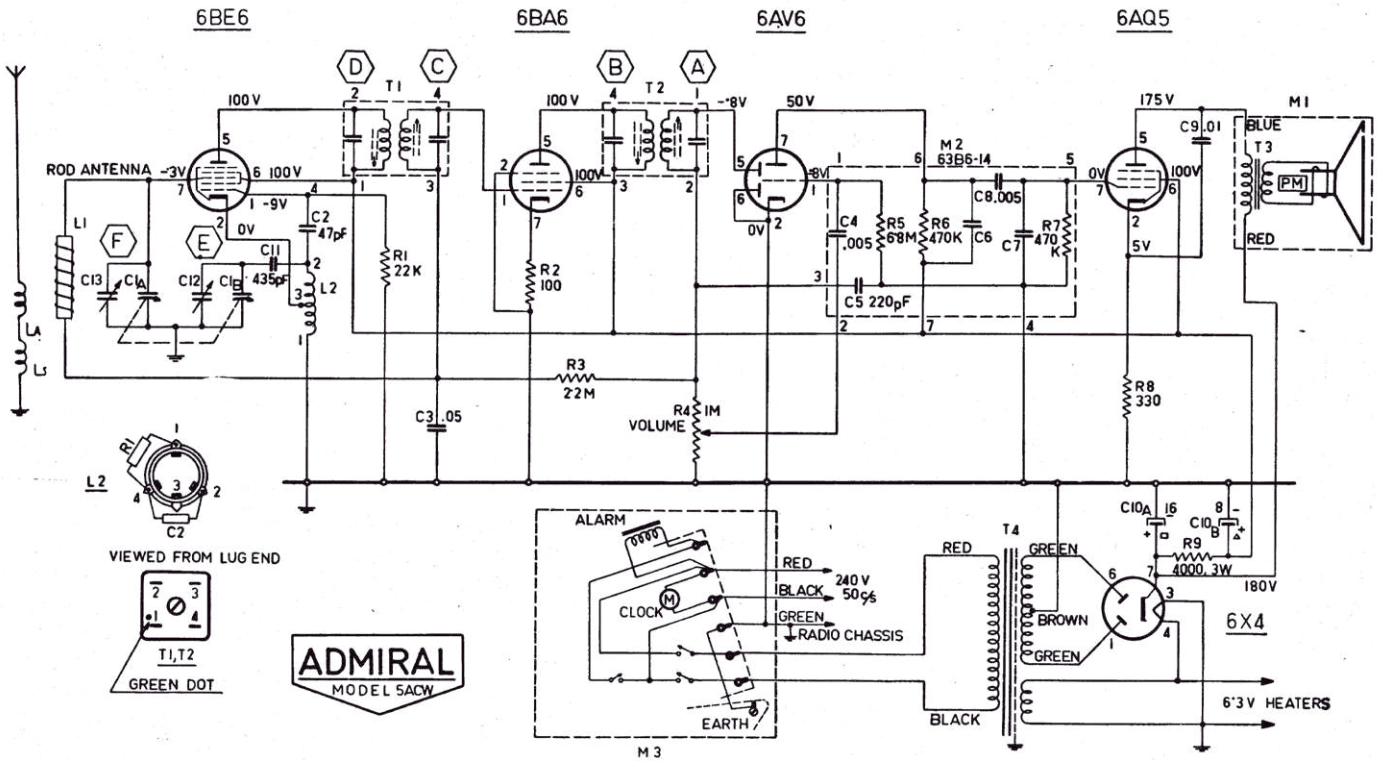
It's highly advanced in some respects, yet conforms to old practices in other areas. The stamped metal chassis is minimalist but still serves as a base for all major components in the way that radios of the 1930s did.

By the 1960s, most radios (by then, transistor based) had a circuit board capable of supporting the ferrite rod and tuning capacitor so that no metal chassis was required.

Circuit details

By 1956, the majority of mantel radios included a ferrite rod aerial. This one has a 10-inch long ferrite rod and it provides excellent sensitivity for local stations. An external antenna and Earth connection are provided using coils wound over the ferrite rod.

The circuit diagram shows two aerial



windings, and these are wound on top of each other, separated by tape. The tuning circuit is a standard superhet configuration using a 6BE6 valve as the mixer-oscillator (converter). The oscillator coil (Hartley type) is mounted on the circuit board adjacent to the 6BE6 valve.

Resistor R1 (22kΩ) and capacitor C2 (47pF) are mounted on the oscillator coil pins rather than on the circuit board. Both IF transformers (T1 and T2) are shielded in standard-size cans, rather than a miniaturised type that was available at the time. This also applies to the two-gang tuning capacitor, which is a traditional full-size type.

The set uses an intermediate frequency of 455kHz. The 6BA6 IF amplifier valve is a common type for this application. It was released in 1946 and is described as a remote cut-off pentode for RF amplification. Remote cut-off refers to the smooth change in gain when grid bias is altered by an AGC circuit.

In this radio, pin 5 of the 6AV6 valve provides the AGC feed to both the 6BE6 and 6BA6 grids via R3 (2.2MΩ), then via the antenna coil for the 6BE6 or T1 for the 6BA6.

The 6AV6 dual-diode/triode is another venerable valve, released in 1947 and intended for use as an audio preamplifier. Pin 5 of the 6AV6 (a diode) acts as a detector and audio is passed to the 6AV6 grid via 1MΩ potentiometer R4, the volume control.

Pin 7 of the 6AV6 (the plate) feeds into pin 6 of a 7-pin package encapsulating the passive components between the audio preamplifier and the 6AQ5 output pentode.

The author has not seen such a package in other Australian radios before the 1960s. Admiral Australia was fortunate to be a subsidiary of a US parent company at the forefront of advances in component fabrication (see history box).

Audio is fed to a 4-inch speaker via an output transformer with a primary impedance of 16kΩ to match the 6AQ5 pentode. The 6AQ5 is a repackaging of the common octal-based 6V6 valve, released in 1936.

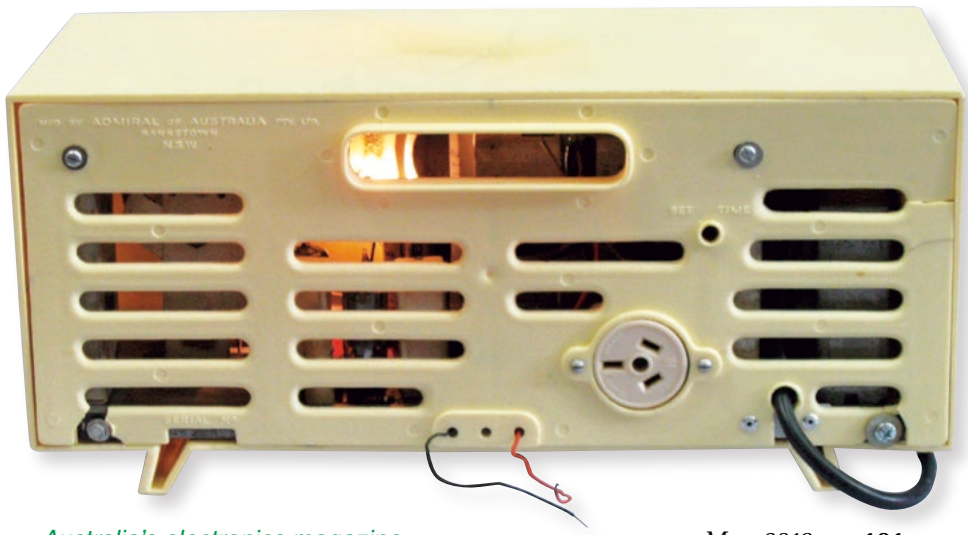
The HT power supply produces 180V DC. This is the value given on the circuit diagram, and I measured my radio as producing very close to this.

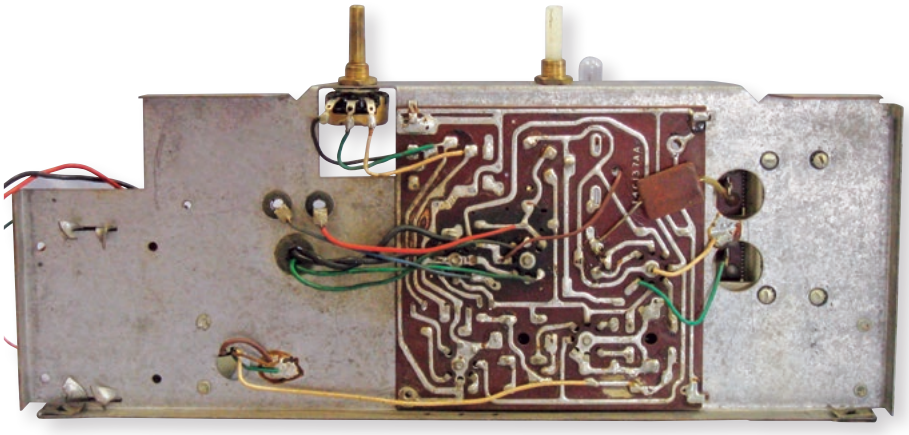
Other measured voltages were slightly above the values indicated on the circuit diagram, probably due to using a DMM rather than an analog meter, which would have a higher burden current.

Physical construction

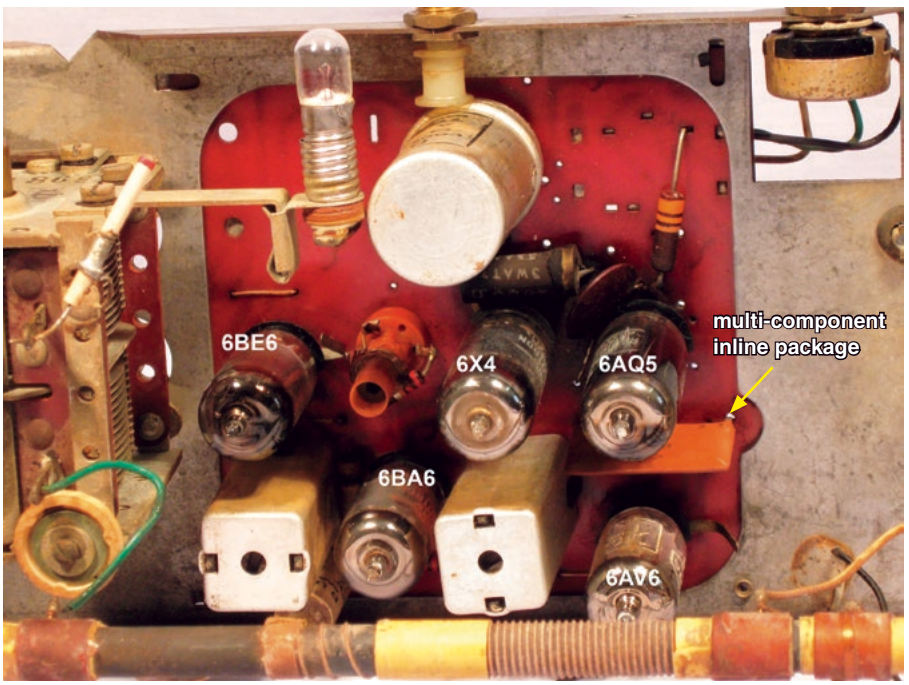
All the miniature valves in this radio are 7-pin types, so all valves use the same base to mount on the circuit board.

The HT filter capacitor mounting arrangement is simplified by having both electrolytics (16µF & 8µF) in a single





The Admiral 5ACW was one of the earliest radios to use a printed circuit board. Note the scorching around the base of the 6X4 rectifier valve.



The multi-component inline package ("couplate"; M2), visible above, contains a few resistors and capacitors in a 7-pin package. It is shown in the dashed box on the circuit diagram between the 6AV6 and 6AQ5 valves.

can with connecting pins at the base.

The phenolic circuit board is of minimal size, so the five valves form a tight cluster; hence, they represent a focal source of heat as they dissipate most of the 27W that this radio consumes at 230V AC. A heat-stress crack had formed in the case of this radio above the circuit board as a result.

Valve-based circuit boards often show scorching of the phenolic material around valve bases. This one was slightly stressed around the 6X4 rectifier base and the adjacent 6AQ5 output valve.

The circuit board soldering was obviously done by hand, but neatly.

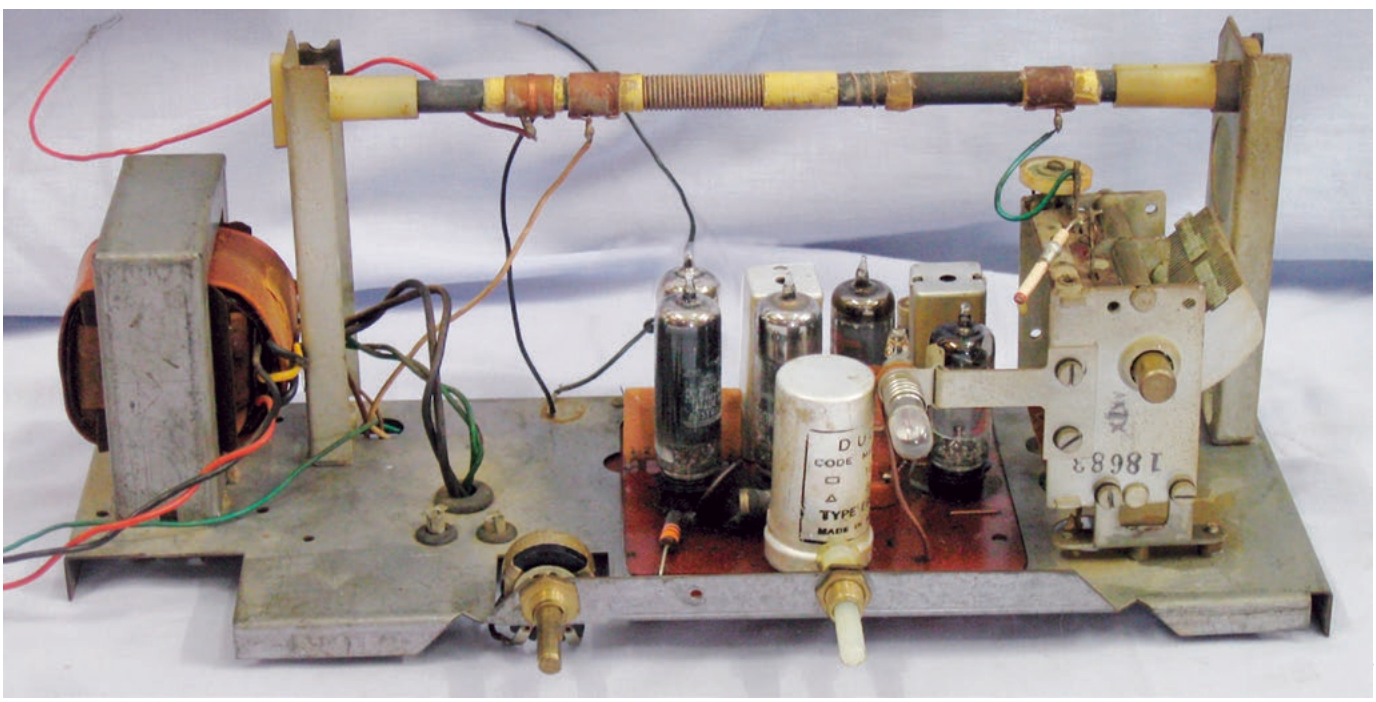
In the context of the pioneering use of circuit boards, the contemporary Admiral transistor radio model 8K2 is also worthy of mentioning. All other Australian transistor radio manufacturers through the 1950s still used point-to-point wiring.

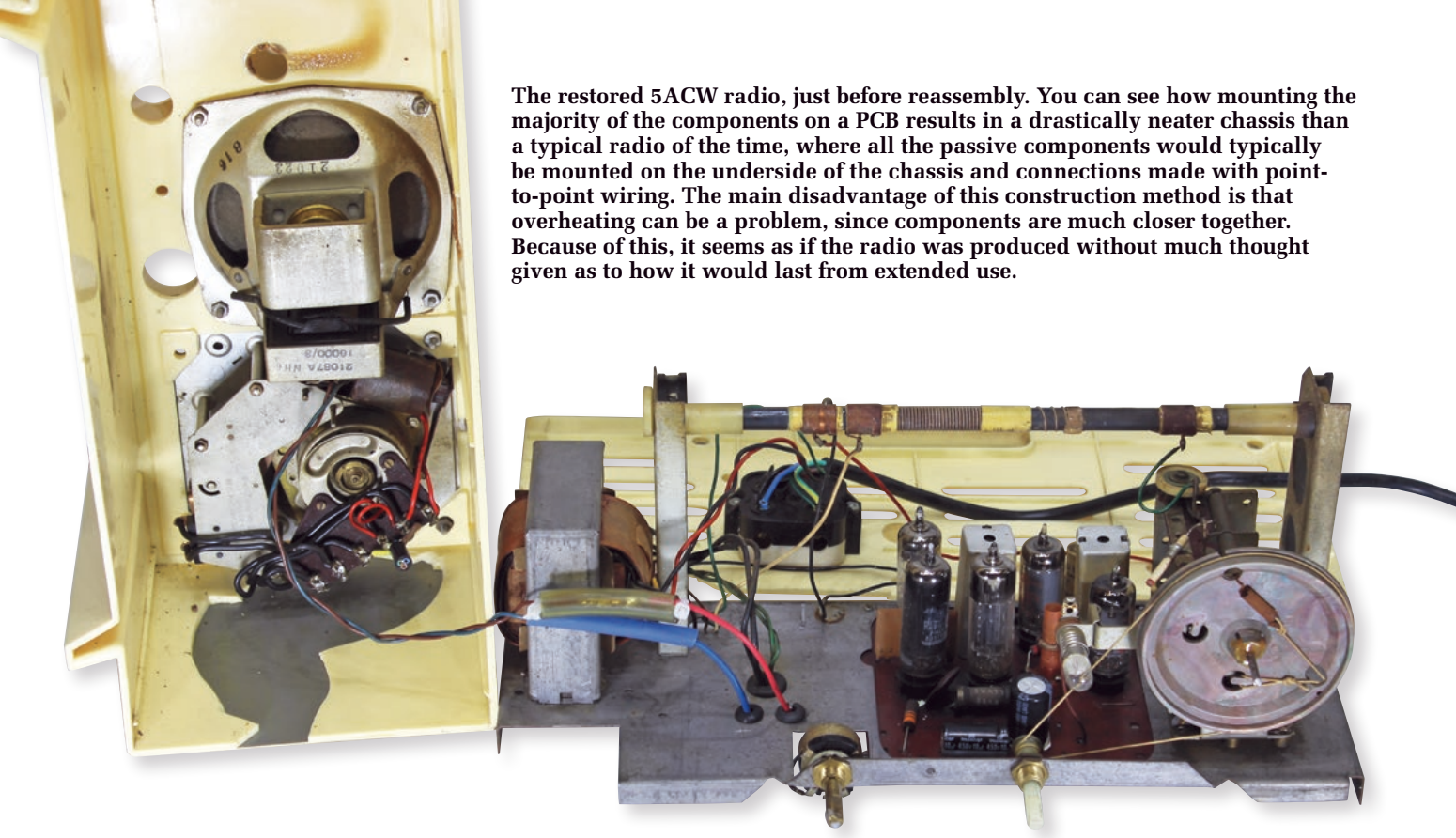
The speaker

Admiral sourced their speakers from AWA who branded their products as Manufacturers Specialty Products (MSP), ostensibly to obscure the source as a competing radio company.

The speaker has a round cone, but the frame is pressed with wide flanges for the mounting screws. The type of permanent magnet used here would soon disappear as the advantages of ferrite magnets became evident.

Despite the speaker's limitations, the radio has excellent sound for a compact mantel type. The speaker has flying leads terminating in plugs that





The restored 5ACW radio, just before reassembly. You can see how mounting the majority of the components on a PCB results in a drastically neater chassis than a typical radio of the time, where all the passive components would typically be mounted on the underside of the chassis and connections made with point-to-point wiring. The main disadvantage of this construction method is that overheating can be a problem, since components are much closer together. Because of this, it seems as if the radio was produced without much thought given as to how it would last from extended use.

fit sockets mounted in rubber grommets through the chassis.

This arrangement caused me some grief, as related later. A smarter location for the speaker sockets would have been directly on the circuit board.

Restoration

The radio was manufactured with a three-core mains cable, but the rubber insulation had severely perished and so I had to replace the cable with a new one.

Otherwise, it passed visual inspection, so I powered it up and it worked the first time. At least, it did in 2002 when I acquired it.

The inspiration for writing about this Admiral radio was the chance reading of a history of Admiral in Australia, written by Neville Williams in Electronics Australia. After reading that, I took the radio from its shelf and plugged it in, whereupon a mild amount of 50Hz hum was produced, accompanied by an acrid aroma of catastrophic failure.

It transpired that the 180V HT lead to the speaker transformer had shorted to Earth due to a perished rubber grommet in the metal chassis. This overload destroyed the 6X4 rectifier. The canned electrolytics had also failed, with an ooze of electrolyte-goo protruding from the base.

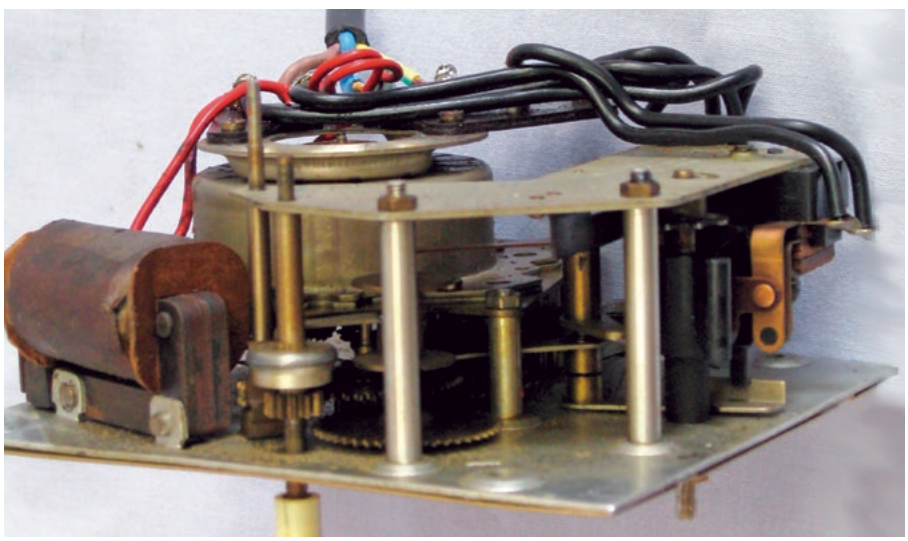
Fixing it was simple enough. I plugged in a new 6X4, replaced the electrolytics in the can with new ones and rewired the flying leads to the transformer to eliminate the sockets.

The post-restoration view of the chassis shown here illustrates other interesting aspects of the assembly.

Admiral Australia was a subsidiary of a US company and they tried to compete fairly with other Australian companies.

However, their innovations and attempts to share their expertise did not endear them to locals and, paradoxically, their success as an Australian manufacturer led to their demise. The history box offers a summary of the rise and fall of Admiral.

Admiral radios and TVs have not become sought after items by collectors, but they deserve to be.



Close-up of the clock portion of the radio, which has an alarm and sleep function. The clock hands were most likely painted with a mixture of radium, zinc sulphide and copper which glows green in the dark. While Radium has a half-life of 1600 years, this dial had no glow because the zinc sulphide crystal structure that supports phosphorescence had broken down.

History: Stromberg Carlson, Admiral and the battle they both lost

This summary is condensed from a two-part history written by Neville Williams and published in *Electronics Australia* (September & October 1994 issues). Scans of the two original articles will be available as a free download from the SILICON CHIP website. Look for items listed in the SILICON CHIP Online Shop under Electronics Australia.

Admiral had established an excellent range of TVs in the USA and decided to make a range of TVs available for the launch of Australian TV in 1956, coinciding with the Melbourne Olympics.

Competing Australian manufacturers started a smear campaign against Admiral even before they arrived, alleging that they would use lethal transformer-less sets and that their 21-inch sets would be too large for normal comfortable viewing. Admiral was already making 29-inch sets in the USA at the time!

This adverse environment did not stop Admiral from appointing Eric Fanker, previously chief engineer with Tasma, as founding Australian General manager. Fanker was an excellent choice and immediately started building a skilled workforce by attracting top staff from other Sydney manufacturers.

In May 1955, Admiral was set up on the mezzanine floor of the old General Industries Refrigerator Factory at Waterloo, Sydney. A large new factory was subsequently purpose-built at Bankstown.

Fred Hawkins moved from Stromberg-Carlson and was given the initial assignment of developing a range of radio receivers, primarily to give the Admiral tradename exposure on the local market before TV arrived.

The range of radios was to include a five-valve mantel set, also to be offered as a clock radio (ie, the radios featured in this article).

These mantel radios would be in the popular Swedish style, new to Australia. Fred Hawkins was directed to use printed circuit boards with the first batch imported from the USA. A local supplier, thought to be RCS, was to produce the circuit boards.

As far as most people were aware, Admiral used the very first circuit boards in Australian consumer electronics. RCS had been making circuit boards for smart munitions during WWII, but that was top secret at the time. There was no logical reason for Australian manufacturers to ignore the advantages of circuit boards; they were just reluctant to change established practices.

At the time, Ducon in Australia could not supply Admiral with capacitors that were designed for mounting on circuit boards. Admiral provided examples from the USA and Ducon expanded its range of packages to facilitate circuit board mounting.

Admiral's primary objective was to produce state-of-the-art TVs. Eric Fanker tried to warn other manufacturers against launching with obsolescent technology, but this advice was ignored with considerable hostility.

The first Admiral TV sets, as illustrated by the Ansett TV, had front-mounted dual-concentric knobs for channel selection/fine tune and volume/contrast. The knobs gave Admiral TV sets a distinctive 'two-eyed' appearance.

It was mandated that the front glass had to be safety glass in case of a CRT implosion. Because the Admiral design was unique, Pilkingtons required a large order to produce them and thousands of glass screens were ordered.

Admiral set out to have a higher throughput of TV sets than any other Australian manufacturer, and they succeeded.

Others watched on incredulously. These were highly reliable sets built on circuit boards with excellent picture quality. However, they had a low audio output of around 1W that others seized on to denigrate the brand.

Admiral had set up a network of retail distributors and in the first two years, Admiral made healthy profits from their TV sales. However, in late 1957, a credit squeeze severely reduced the number of buyers for TVs.

Coinciding with this, a glass manufacturer strike meant that Admiral's competitors could not source the safety glass they needed for their cabinets. This was a seeming windfall for Admiral who had large stocks of their cabinet glass and they ramped up production to compensate for the stoppage forced on other manufacturers.

Eventually, they had a stock backlog of 5000 units which were proving difficult to move. It was not the bonanza it should have been.

Admiral made a bulk purchase arrangement with retailer H. G. Palmer so that they could retail Admiral TVs at a bargain price.

This did solve the short term problem, but the bargain price was close to the wholesale cost to the Admiral network of dealers, and so these resellers dumped the Admiral brand. Admiral could see no light at the end of the tunnel. The factory site had appreciated considerably, so they sold it and thus ended Admiral in Australia.

There is one more sting in the tail of Admiral's closure: not having learned from Admiral's mistake, Stromberg-Carlson stepped in as a discount supplier to H. G. Palmer.

Dealer networks then dumped Stromberg-Carlson, just as they had dumped Admiral. Stromberg-Carlson could not service its debt and was also wound up as a result. SC

This Admiral TV had pride of place in the Mount Eliza lounge room of aviation and television pioneer Sir Reginald (Reg) Ansett. Sir Reginald launched Melbourne's Channel 0 (later Channel 10). The Ansett TV is now held in the collection of the Australian Centre for the Moving Image (www.acmi.net.au).

PRODUCT SHOWCASE

Facility Management – Emergency Plans with AARC-EVAC

Managing a facility's emergency plans requires an effective response to all potential emergencies. There are many different types of emergency situations, including fire or explosion, dangerous gas release, medical emergencies, natural disasters, bomb threats, threats of violence and robbery.

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The AARC-EVAC technology has been developed in Australia and the systems are being manufactured in Australia by AARC Systems, an Australian company located in Ballarat, Victoria. Based on an assessment of customer needs, the developers spent three years on R&D prior to launching AARC Systems Holding Pty Ltd and commercialising the AARC-EVAC system. Initially, much of the R&D effort was centred around the development of the proprietary radio network that links the system together, which had to be extremely reliable and robust.

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Arduino IDE GCC compiler bug

When compiling the software for the Diode Curve Plotter (March 2019; siliconchip.com.au/Article/11447) in the Arduino IDE, I get the following error:

Arduino: 1.8.4 (Windows 10), Board: "Arduino/Genuino Mega or Mega 2560, ATmega2560 (Mega 2560)"
C:\Users\JBA\Documents\schip\Zener_Diode_Tester\Zener_Diode_Tester.ino: In function 'findTargetPowerIndexFloat':
Zener_Diode_Tester:884: error: unable to find a register to spill in class 'POINTER_REGS'

Could you please guide me to a solution? (J. A., Townsville, Qld)

● This is due to a bug in the GCC compiler which is used by the Arduino IDE. This bug appears to be intermittent and is described here:

https://forum.arduino.cc/index.php?topic=510473.0

You are using Arduino IDE version 1.8.4 and we used version 1.8.5 for this project, so we recommend upgrading your IDE version to see if that helps. Alternatively, you may be able to update the compiler by using the Tools → Board → Boards Manager menu. Look for "Arduino AVR boards" and see if you can upgrade this to version 1.6.23.

Diode curve plotter opto voltage ratings

Regarding the Multi Diode Curve Plotter in the March 2019 issue (siliconchip.com.au/Article/11447), you have specified PC817 optocouplers. I have some similar "LiteOn" LTV817 parts which seem much the same, but the maximum collector-emitter voltage is specified as 35V.

Since the boost converter in this project produces around 100V DC, will these optocouplers be OK with switching this? (R. S., Emerald, Vic)

● They should be fine; even the specified PC817 optocouplers do not have a 100V rating. The optocouplers are in series with the high-voltage supply, so only a portion of it appears across them. The software limits the voltage across the optocouplers so that they are not exposed to the full 100V.

Diode Curve Plotter discrepancy spotted

I have a couple of questions regarding the Multi Diode Curve Plotter in the March 2019 issue (siliconchip.com.au/Article/11447).

I have received the PCB I ordered from your Online Shop and noticed that three resistors just to the left of D1 are all shown as 10kΩ in Fig.2 on page 67 but the PCB silkscreen, circuit diagram and parts list all show the middle resistor as 1kΩ. I assume that Fig.2 is in error.

The photo of the populated PCB shows a nice neat 1µF capacitor. Where did you get such a small and compact polyester capacitor? All the 1µF 250V caps from the usual suppliers have a lead pitch of 20-25mm. The only small electro I could find in 1µF, 450V is RS Cat 365-4795. (P. C., Woodcroft, SA)

● You are correct, the 1kΩ resistor just to the left of and slightly above D1 has been wrongly marked as 10kΩ on Fig.2. We will publish an erratum.

The 1µF capacitor seen in the photo is a 1µF 100V unit from Jaycar (RM7170), which was used for prototype testing. It was fine running right at its voltage rating; however, we thought it safer to specify a 250V-rated capacitor for the final version to give a bit of headroom, as the boost converter output can exceed 100V.

Which transformer to use for Magnetometer

I want to build the Incredibly Sensitive Magnetometer project you published in your December 2018 issue (siliconchip.com.au/Article/11331). But the article doesn't specify the part number of the transformers used as the sensing coils, and I am having difficulty finding one with the specified secondary ratings of 12V, 10A. Do you know where I can get one? (anon, via telephone)

● Pretty much any non-toroidal transformer with a 12V, 10A secondary (or similar rating) should be acceptable. For example, RS Cat 504-127 (siliconchip.com.au/link/aapt).

Alternatively, Tortech (www.tortech.com.au/store/) sell 12V transformers with a 150VA rating for $64 including GST.

Both of these transformers above have dual secondary windings, while the transformers used in the prototype Magnetometer had a single winding. For transformers with dual secondary windings, connect them in parallel. It should work with them connected in series too, but the circuit would then behave differently, and this has not been tested.

The prototype transformers were old stock of a lighting company, not advertised on the internet; hence we did not give specific part numbers. The exact VA rating is not critical. For example, 12V 15VA transformers are suitable for detecting, through a tabletop, that someone has moved one's keys or mobile phone.

Sourcing Clipsal plates for Dimmer project

Could you please advise where you obtained the Clipsal 2000 series blank plate and cover for the Versatile Trailing Edge Dimmer project (February & March 2019; siliconchip.com.au/Series/332). I can't find a local source for them. (J. A., Townsville, Qld)

● You need to order these from an electrical wholesaler, one that sells to electrical contractors including lighting, cabling, power points and the like. They don't usually have stock of the specific Clipsal parts required, but these can be ordered.

John Clarke purchased the ones used in the prototype from Lawrence and

Hanson, although many other suppliers can order the Clipsal parts, eg, John R. Turk. Look up "electrical wholesaler near me" online.

Converting LPs to MP3s

I would like to copy my LPs to a USB memory stick to listen to in my car. Can I connect my turntable to an analog-to-digital converter board fed into a USB socket to achieve this? Is an intermediate amplifier needed, between the turntable and the analog input? Could an Arduino Mega be used? (M. P., Croydon, Vic)

● You need an RIAA preamplifier to boost the low-level signal from the magnetic cartridge on the turntable up to line level, and also to provide the correct equalisation. Otherwise, the result will sound wrong. You can then feed the output of the RIAA preamplifier into a computer for recording.

We published an article on how to do this in the September 2006 issue, called "Transferring Your LPs to CDs & MP3s" – see siliconchip.com.au/Article/2769

Our latest RIAA preamplifier design was published in the August 2006 issue. The article was titled "Build A Magnetic Cartridge Preamplifier" (siliconchip.com.au/Article/2740) and a kit for that project is still available from Altronics (Cat K5513). We also sell the PCB for that project in our Online Shop (siliconchip.com.au/Shop/8/860).

Once you have a suitable RIAA preamplifier connected between the output of your record player and audio input on your computer, you can use free software such as Audacity (www.audacityteam.org/download/) to record the audio.

To save the result in MP3 format, you also need an encoder called LAME, which interfaces with Audacity and can be downloaded from: https://sourceforge.net/projects/lame/

Trouble getting banana plug sockets

I notice that the PCB-mounting banana sockets used in the Wide-range Digital LC Meter project (June 2018; siliconchip.com.au/Article/11099) – specified as Altronics Cat P9200 & P9201 – are no longer listed on the Altronics website or in their latest catalog.

Can element14 Cat 1698982 be used instead? I'd welcome other alternatives. (S. E., Scullin, ACT)

● It is unfortunate that these parts have been discontinued not long after we've used them in a few different projects.

The dimensions of the part that element14 sells look similar to the ones we used but not identical (for example the pins are 1.3mm vs 1.2mm wide), but we think they will probably fit on the PCB and do the job, even if they are not a perfect match.

Another reader pointed out these sockets from eBay; again it is hard to be certain that they are an exact match, but they will probably be close enough: www.ebay.com.au/itm//152700921462

We will try to find a source of these parts so we can sell them in our Online Shop, to make it easier for readers to build this project.

Different relay versions causing problems

I just built the Wide-range Digital LC Meter (June 2018; siliconchip.com.au/Article/11099). The build was straight forward, and when I powered it up, I was greeted with the initial screen displaying the values of L and C. I could connect to it using my laptop and adjust the parameters.

I tried measuring a 10µF capacitor but the test frequency only read 0Hz or 10Hz. I used my DMM to check for driving signal for the relays on the Arduino digital outputs at D6 to D9, but I only read just over 1V; not enough to trigger the relays.

I decided to de-solder one relay and the reading on that driving pin was then 5V. I concluded something was wrong, so I desoldered the three other relays, and discovered they would only switch on if the power was ap-

Current rating of 12V Motion-Sensing Power Switch

As the owner of a vehicle with the unswitched auxiliary power outlet 'feature', I'd like to say what a pleasant surprise the Motion-Sensing 12V Power Switch project was in the February 2019 issue (siliconchip.com.au/Article/11410). I have already ordered a short form kit of parts.

I had been contemplating building an automatic switch myself and had gone through similar thought processes as Nicholas Vinen but had not turned it into reality. What modern manufacturers are thinking when designing car electrical systems is sometimes a mystery.

In addition to the unswitched power outlets, my vehicle's exterior sidelights come on whenever a door is opened; it does not matter if the light switch is on or off. I've lost count of the number of helpful bystanders who point out I have my lights on when loading the car at the supermarket. I then have to explain that this a feature of the car and not me being forgetful.

One thing not covered in the article is the maximum current allowed through the circuit. I plan to connect a dashcam, navigation device and transceiver with a current draw of 12A on transmit for say a total of 15A maximum. The IRF4905 appears to be rated at 50A, providing the wiring can take the load, should it be OK? Keep up the great work. (N. D., Ocean Beach, WA)

● Thanks for the feedback. Sometimes manufacturers do not think through the ramifications of doing things in an unusual way.

Practically speaking, the device as presented should be good for around 5-7A. While the IRF4905 is rated higher than that, it would need heatsinking. Even at 7A, the TO-220 package would get pretty hot. The SMD version should not be used in situations where the current draw would exceed 5A.

There are alternative Mosfets which could handle up to 15A without heatsinking. You would need one with an on-resistance of 4mΩ or less. For example, these should all be suitable: AOT240L, CSD18511KCS, IRFB7437PBF, IRFB7446PBF.

As you say, the wiring would need to handle this current to, as well as the plug and its integrated fuse (and make sure to solder those wires close to the Mosfet leads).

DAB+/FM/AM Radio audio transistors overheating

I am having trouble with transistors Q1-Q4 in the DAB+/FM/AM Radio (January-March 2019; siliconchip.com.au/Series/330) overheating. I replaced the transistors with new ones and have thoroughly checked the circuit against the schematic, and everything checks out. I can find no short circuits. But they're still overheating.

They get too hot to touch shortly after switch-on, and both the -5V and +5V rails are pulled down as a result. With the transistors removed, the rest of the board seems OK and the voltage rails remain stable. Any idea as to where to look next would be appreciated. (D. E., Wattle Park, SA)

● We had problems with these same transistors overheating in our second prototype and it turned out to be a bad solder joint in one of the feedback resistors near op amp IC5 (from memory, one of the 2.2kΩ resistors). That was causing the op amp's output to swing wildly from rail to rail and thus causing the transistors to overheat. Resoldering that resistor fixed it.

But that was just one pair of the transistors as only one channel was affected by this fault. It sounds like the transistors in both channels are overheating on your board.

Try (quickly) measuring the voltage across D1 & D2. You should get a reading around 1.2V in both cases. If one or both are much higher, they could be over-biasing the transistors.

Try removing the two 2.2kΩ resistors at either end of D1 & D2. If those transistors still overheat then there is something wrong with the devices; either they are in the wrong locations or are the wrong types.

If that does stop the overheating, then try fitting a higher value resistor pair to one diode, eg, 10kΩ or even 22kΩ. Perhaps your BAV99s have an unusually high forward voltage, or your BC807/BC817s have unusually low V_{BE}.

That would result in a much higher quiescent current than in our prototypes and could result in what you have described happening.

plied with the opposite polarity to how they were wired on the PCB. So, I then cut their coil leads and used two wires to swap them and solder them back on the PCB.

After reapplying power, the four relays were triggered correctly and I could hear the (discreet) click. So the internal flyback diode wiring was the opposite of the specified relays. The unit then gave accurate readings with various test capacitors and inductors.

One thing I noticed is while I can specify the value of C_P and L_P from the terminal, I cannot enter a value for R. No matter if I chose a unit or not, no value will be written in the Arduino memory. I tried changing the default value in the code (line 656 onwards), but it always displays 130Ω on the LCD upon startup. Any idea why? Thanks and keep up the good work! (O. A., Singapore)

● None of the relays that we tested for the LC Meter had internal diodes, so we did not suffer these problems. We checked the data sheet for the relays we used (TRR1A05D00) and it does not show any diode or polarity marking on the coil.

We tested the calibration menu just now and we were able to change the R value by typing either "140" or "140R" (and "S" afterwards to save). The new value is loaded from EEPROM when we reset the unit.

The default value for R1 is also set on line 49 of the sketch; this sets it to a sensible default in case the EEPROM is empty. We suggest that you try changing the values at line 49 and line 656 and wipe the EEPROM to be sure any remnants are gone.

Battery charger inrush current limiting

I am having troubles with my battery charger, and it occurs to me that you could create a small project which could be of use to me, as well as appealing to others.

I have a solar system with battery backup and use a mains-powered battery charger as a further backup. As my mains voltage tends to sit around 253V AC, the charger often blows fuses or breaks down when switched on, due to the high surges involved. What I need is a slow start device, which will cope with a 10A load current, and the surges involved.

Possibly this could be a variation of your latest mains motor speed controller, built in a small box with flying leads and incorporating a microcontroller and Triac. The timing could be controlled by a jumper, with a range from a few seconds (large motors) through a minute (my charger) to several minutes (large valve amplifier). (D. T., Yallourn, Vic)

● Switch-on surges usually only last a few mains cycles unless the device has a big motor in it that takes time to spin up. And even then, the worst is usually over within a second or so. Did you consider building our Soft Starter for Power Tools? (July 2012; siliconchip.com.au/Article/601)

It's load-sensing so is suitable for devices which have their own power switch or where they switch on automatically. For basic soft starting where you're switching on a device at the wall, the simpler April 2012 Soft Starter is suitable (siliconchip.com.au/Article/705).

You might also want to look at our March 2011 Mains Moderator (siliconchip.com.au/Article/937), a low-cost unit to reduce high mains voltages for devices that draw up to 450W, although it can be built to handle more power.

Automotive Sensor Modifier questions

I am thinking of building the Silicon Chip Automotive Sensor Modifier. Can you supply the PCB and if so, does it come with the components? If not, where do I buy those components from? Also, can the Sensor Modifier convert a sensor voltage from 1.2-4.5V to 0.5-4.5V? (S. W., via email)

● For this project, we sell the PCB (Cat SC4068) and programmed PIC microcontroller (CAT SC4069). You can get the other parts from suppliers such as Jaycar, Altronics etc.

If you do not have the parts list and instructions, you will find these in the magazine article. You can buy the printed magazine from siliconchip.com.au/Shop/2/4077 or access to the

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05/19

GPS Frequency Reference not calibrating properly

I built the GPS-synced Frequency Reference (October-November 2018; siliconchip.com.au/Series/326), but it isn't working properly. I have been trying to fix it for a few weeks. All indicators in the Status screen are fine but the output frequencies are way off the mark. I'm checking them on my HP 5335A counter which uses an external GPS-locked 10MHz reference.

After the unit has been running with a GPS signal for over 24 hours, the 10MHz output reads 10,000,064.89Hz and the VCO Trim C setting is at 0. Gain is at 1000 and Update is 3600. It seems I need to be able to enter a negative figure for the C value to force the 40MHz oscillator to run at the correct frequency, but there is no way to enter a negative value.

I am wondering if the TXEAACSANF oscillator is faulty. Are you able to supply a replacement? Do you have any ideas as to what the problem could be? (M. T., Balgal Beach, Qld)

● The VCO Trim C Value cannot be a negative number. Zero is the lowest it will go. It sounds like either the TXEAACSANF oscillator is faulty, as you suggest, or its trim input is not being driven by the DAC properly.

With a C Value of 0, you should be able to measure close to 0V at the output of the DAC (pin 6 of IC3). This should ramp up to 2.5V with a C Value of 16,000,000.

If this is not what you are seeing, there may be a problem with DAC IC1, op amp IC3 or one of the signal lines between the Micromite and IC1.

online version from siliconchip.com.au/Shop/12/4078

Yes, the Sensor Modifier can change the sensor voltage range up or down according to the map of input versus output that is entered. So it can shift a 1.2V input signal down to a 0.5V at its output while leaving a 4.5V level signal unchanged. The main restriction is that both the input and output signal ranges must be between 0V and 5V.

Motor speed controller with external pot

I recently built your June 1997 High-Current Speed Controller for 12/24V Motors from a Jaycar kit (Cat KC5225). I'm using it to control a car wiper motor that rotates my telescope dome. The kit worked fine right off, so thank you for a good design and article.

Is it possible to replace the trimpot on the board with an off-board 5kΩ potentiometer? I want to be able to make occasional changes to the rotation speed once the board is housed. If so, would I be correct in assuming that it should be a linear pot? Thanks for a great mag! (N. F., via email)

● Yes, you can use an external potentiometer and the resistance law required is linear.

Multi-spark CDI transistor failure

Thanks for the fantastic series of automotive electronics projects! I'm driving a 1989 Mazda B2000 ute with points ignition and carburettor which makes it slow to warm up, and it can run a bit rich.

So I built the Multi-spark CDI unit from the December 2014 and January 2015 issues (siliconchip.com.au/Series/279). It bench tested fine, the engine started straight away and I then happily drove the vehicle for about two months. After driving up a large hill, the CDI unit completely failed. Q1 and Q2 had blown to pieces.

I am about to rebuild it but I would like to know why it failed. One clue is that before it failed, the vehicle battery became discharged twice. I had to remove it from the ute and recharge it. I figured the battery was old and needed replacing, but I didn't. Perhaps the CDI discharged it. I'm guessing the CDI low-voltage cut-out feature operated, switching the unit off once the battery was flat.

So perhaps the CDI unit was drawing too much current from the battery? I am suspicious of the internal dead time comparator setting for Q1 and Q2. Could they have been shorting the 12V supply when switching? When I rebuild the circuit, I will check this with an oscilloscope.

Secondly, I came across a letter in the June 2015 issue about a CDI failure due to a short circuit between turns on the transformer secondary. This would cause the circuit to struggle to reach 300V; thus, the pulse width driving Q1 and Q2 would increase. Perhaps this could lead to overheating?

When I get the unit running again, what should I expect its current draw to be? I could temporarily connect the ballast resistor back in series with the 12V supply and measure the voltage across it.

Regarding the coil, with the new CDI unit installed, I kept using the same coil that was used with the ballasted points system. It has a primary resistance of about 1.6Ω. I noticed that in the first article, the Bosch GT40 coil is mentioned. These are designed for use in ignitions without a ballast resistor and have a primary resistance of about 3.6Ω.

So by using the lower impedance coil, could I have been over-driving the poor CDI unit until Q1 and Q2 fried themselves? That might explain why the unit worked for a while before failing (although I reckon it should have worked better than it did). (B. N., Dunedin, NZ)

● The complete failure of Q1 and Q2 suggests that the unit overheated until meltdown. Possibly it is a shorted turn in the transformer, as you suggest. Or as you say, it could be that the drive to the Mosfets does not have the correct dead time. Check the gate drives to the Mosfets to make sure these are correct before re-connecting transformer T1.

It should not matter what ignition coil is used, whether it is a ballasted points type or the Bosch GT40. The Multi-spark CDI should draw no more than 1A at low engine revs.

Muting radio during comms activity

I have a boat with two radio systems, entertainment and marine VHF. I want to use Bluetooth to connect them to a pair of headphones for me to monitor while at the helm, particularly when I am alone. The Bluetooth bit is OK and I am considering using your June 2015 Champion preamp.

Continued on page 112

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Coming up in Silicon Chip

AM/FM/CW Scanning HF/VHF Signal Generator
This low-cost, easy-to-build RF signal generator covers 100kHz to 50MHz and 70-120MHz, and is usable up to 150MHz. It generates CW (unmodulated), AM and FM test signals and also includes a scanning function for filter alignment.

Bathymetry through the ages
Dr David Maddison describes how the use of knotted ropes and timber poles to measure water depth gave way to sonar. But modern sonar is about more than just water depth measurement. It can be used to map the seafloor, for discovering and imaging wrecks and other submerged objects.

Rechargeable LED bicycle light
This device uses a switchmode converter to drive a string of LEDs from a rechargeable lithium-ion battery pack. It has multiple light modes and automatically reduces the LED current to prevent overheating.

Speed-based Volume Control
Newer vehicles can automatically increase the radio/audio playback volume as you accelerate, to help overcome increased road, engine and wind noise. Now you can add this feature to just about any vehicle with this unit. It senses your speed using a GPS receiver and adjusts the audio signal volume accordingly.

12V Battery Isolator
This solid-state device automatically connects an auxiliary battery for charging when the vehicle alternator is running. It can handle charge currents in excess of 100A, does not get hot during operation, produces little to no EMI and has a low current drain when off.

Note: these features are planned or are in preparation and should appear within the next few issues of Silicon Chip.

The June 2019 issue is due on sale in newsagents by Thursday, May 30th. Expect postal delivery of subscription copies in Australia between May 28th and June 14th.

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Notes & Errata

Multi Diode Curve Plotter, March 2019: in Fig.2 on page 67, the resistor to the left of and slightly above diode D1 (in the middle of a group of three labelled 10kΩ) should be labelled 1kΩ. The circuit diagram and silkscreen on the PCBs sold in our Online Shop is correct.

DAB+/FM/AM Radio, January-March 2019: the PCBs we have supplied for this project are marked RevC, but they are actually RevD boards, with the extra resistors as described in the article. They were simply mislabelled. No RevC boards have been sent to customers.

3-Way Adjustable Active Stereo Crossover, September-October 2017: there is a mistake in the PCB design which means that if a transformer with a centre-tapped secondary (or two secondaries connected in series) is used, those secondaries are shorted out when the unit is switched off. To solve this, cut the top layer copper rectangle joining the two front-most power switch terminals between the two pins, or use a RevE PCB, which no longer has these two pins shorted together.

The additional feature I would like to incorporate is for the entertainment channel to be muted when there is activity on the marine channel. Do you have any suggestions on the best way to do this? (G. C., Mount Dandenong, Vic)

- You can use a VOX (Voice-Operated Switch/Relay) to do this. The latest one that we published was in the July 2011 issue of Silicon Chip (siliconchip.com.au/Article/1101). Feed the marine VHF channel audio signal to the VOX input and wire up the entertainment channel to the mixer input via one of the NC/COM relay pairs on the VOX board.

That way, when the VOX board detects activity on the marine channel, the entertainment channel will be automatically disconnected. It will be re-connected after some period of inactivity on the marine channel, as determined by the delay setting on the VOX (VR2). SC

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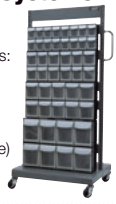

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